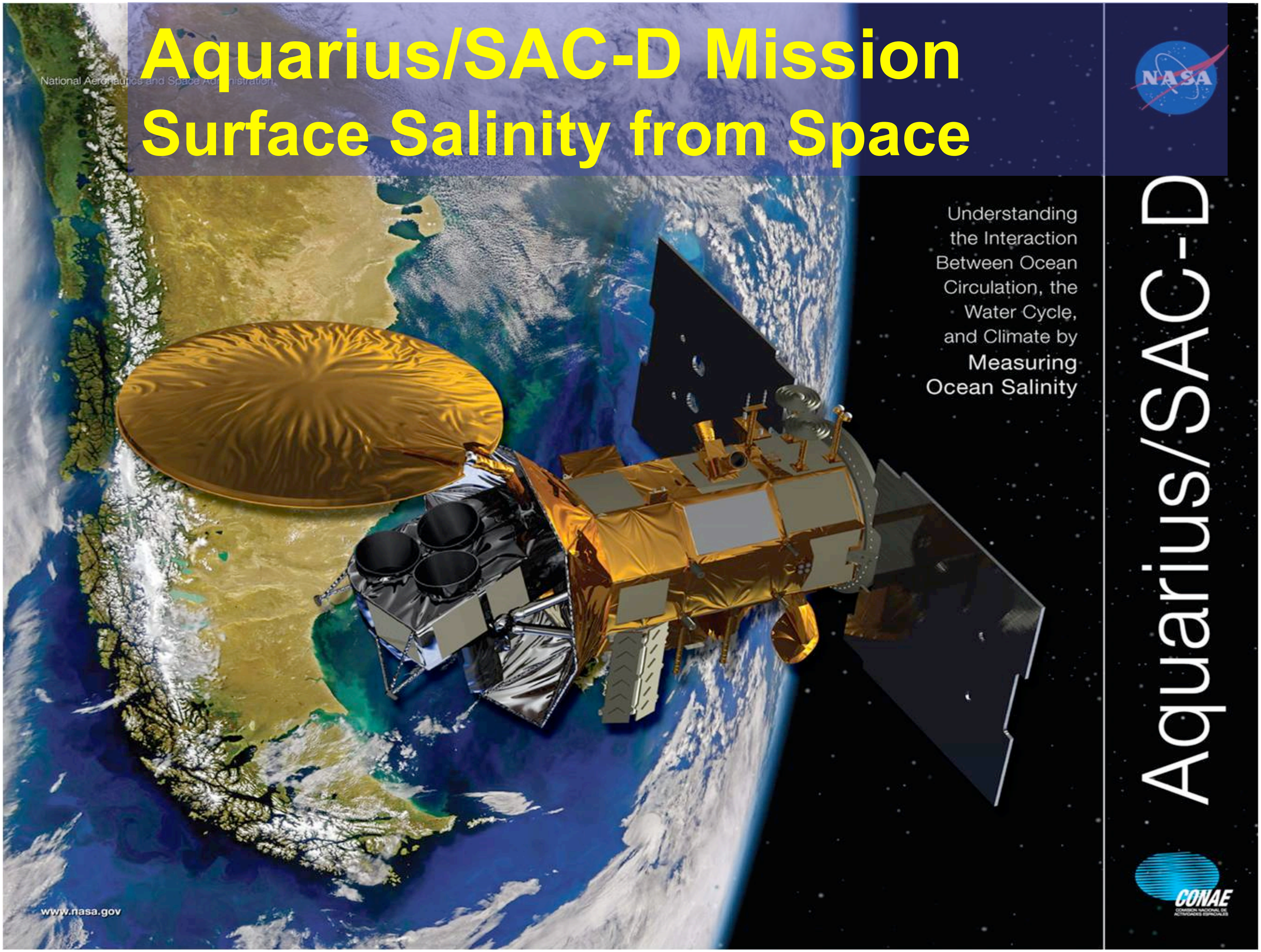
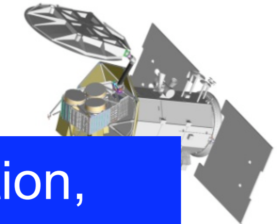
Aquarius/SAC-D Mission
Surface Salinity from Space

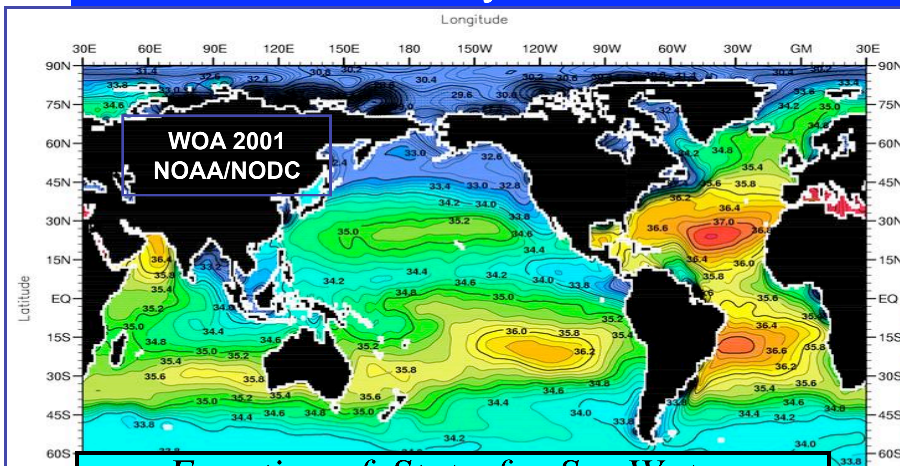


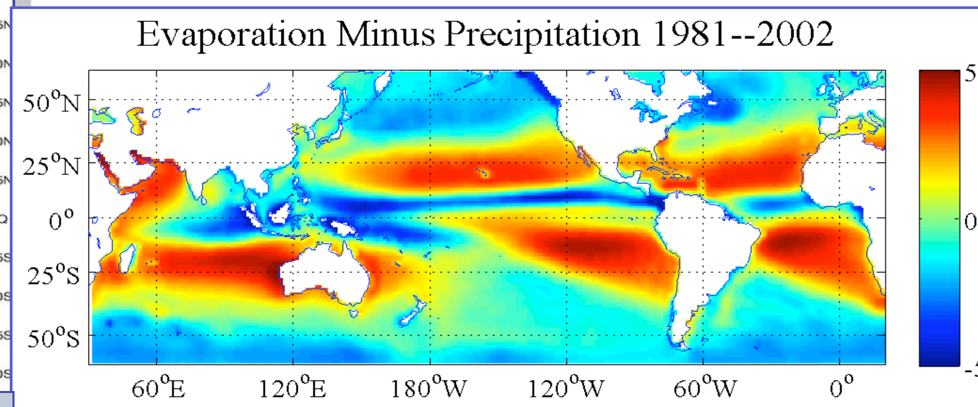
AQUARIUS/SAC-D

Aquarius Mission Science



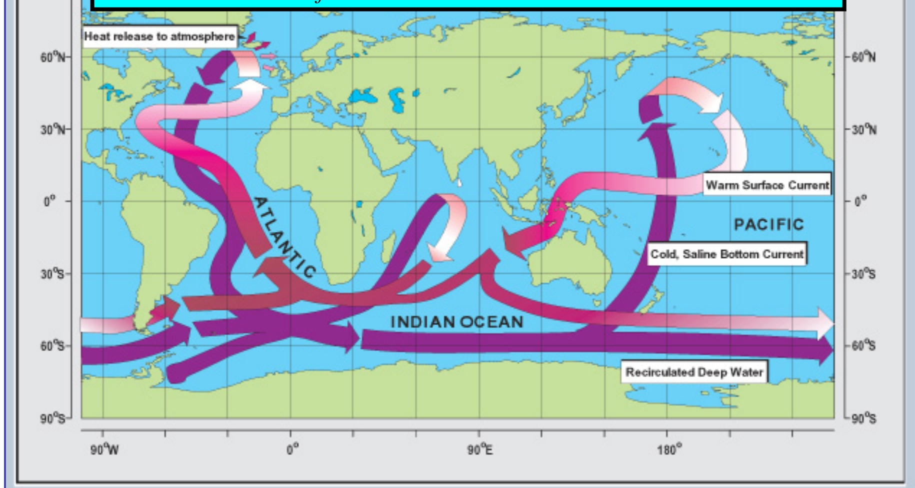
Understanding the Interactions Between the Ocean Circulation, Global Water Cycle and Climate by Measuring Sea Surface Salinity





Equation of State for Sea Water

$$\rho_{sw}(S,T) = \rho_{fw}(T) + b(T)S + c(T)S^{3/2} + dS^2$$



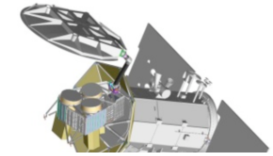
Global salinity patterns are linked to rainfall and evaporation

Salinity affects seawater density, which in turn governs ocean circulation and climate

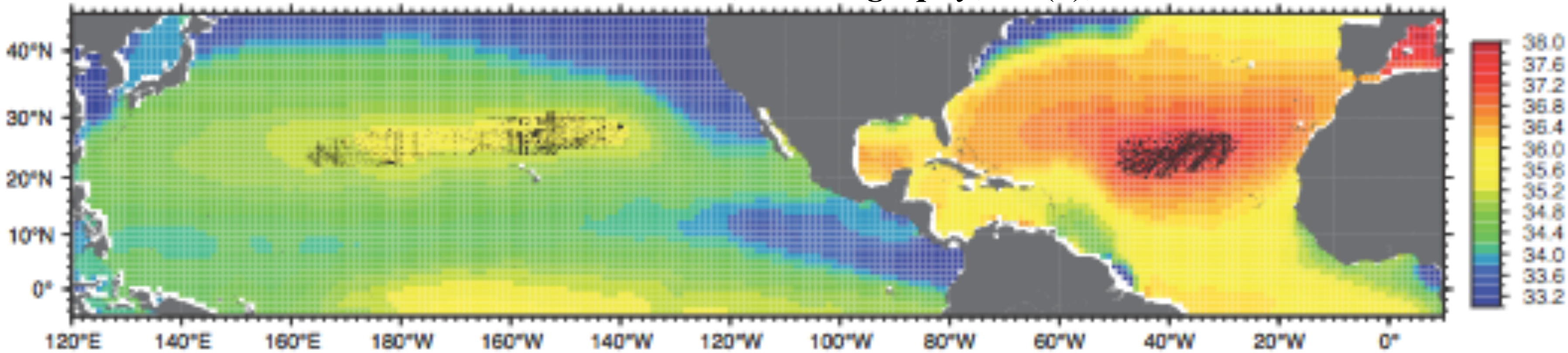
The higher salinity of the Atlantic sustains the oceanic deep overturning circulation

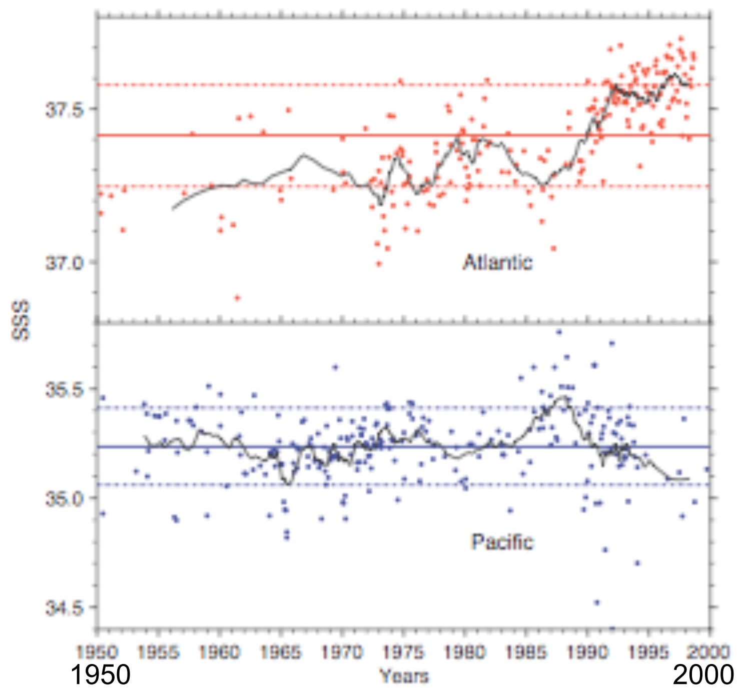
Salinity variations are driven by precipitation, evaporation, runoff and ice freezing and melting

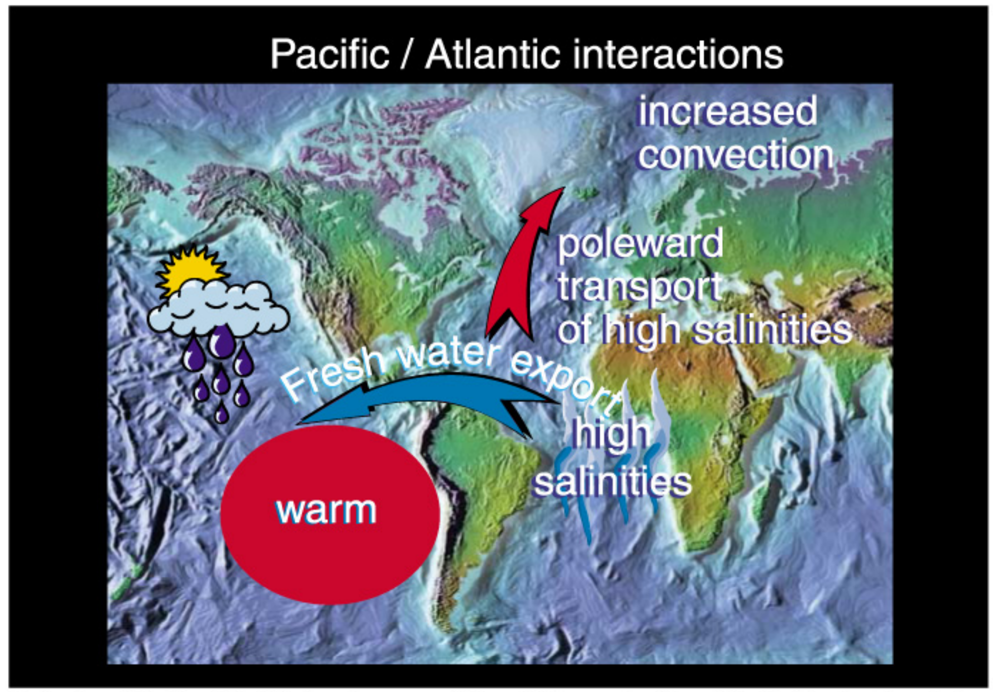
Ocean Salinity Trends; Links to Water Cycle



Gordon and Giulivi, ***Oceanography***, 21 (1), 2008



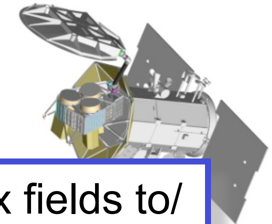


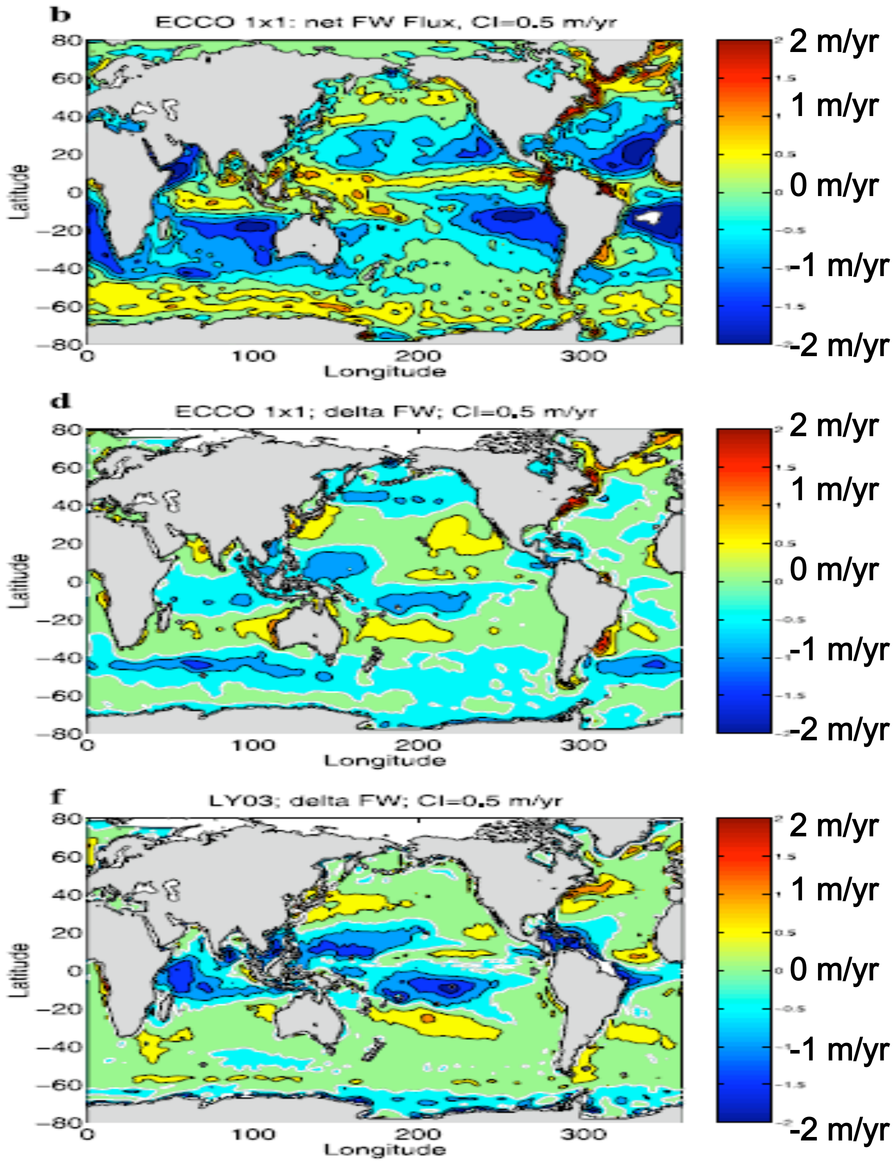


Mechanism of Pacific - Atlantic Interactions on multi-decadal time scales. From, M. Latif, Geophys. Res. Lett., 2001, 28, 538-542 **M. Latif, GRL 2001**

AV/D3/0101

AQUARIUS/SAC-D Marine freshwater budget out of balance





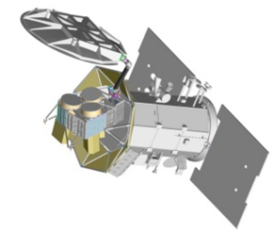
The mean net freshwater flux fields to/ from the atmosphere as they result from the ECCO ocean model optimization over the period 1992 through 2001 (m/year).

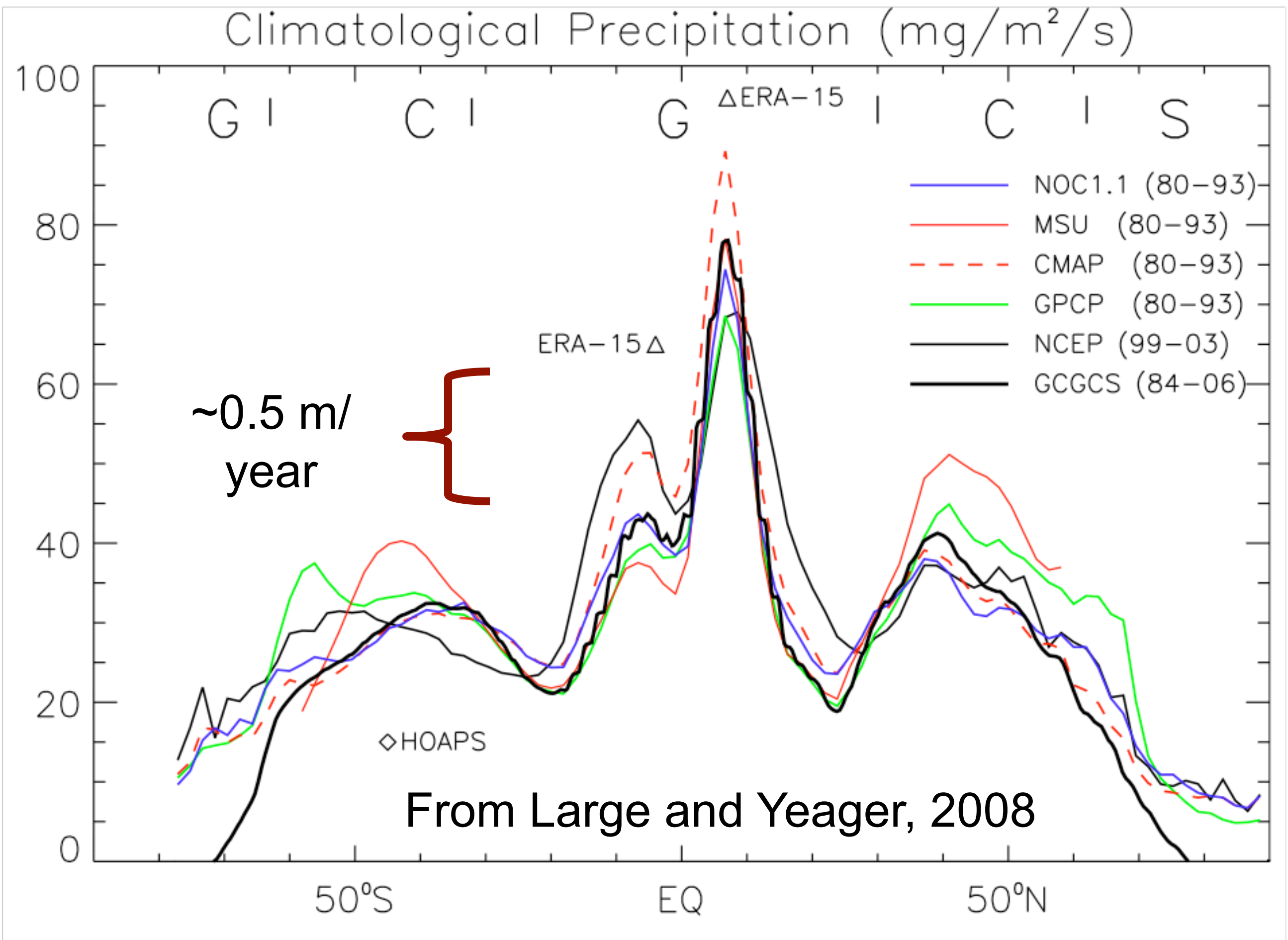
Mean difference between the net freshwater flux as determined from the ocean optimization relative to the NCEP fields estimated over the same period.

Mean fresh water flux difference between NCAR and NCEP for the period 1991–2000, illustrating the uncertainty range of different atmosphere analyses.

(Stammer et al, JGR-Oceans, 2004)

Uncertainty in the Global Precipitation Estimates





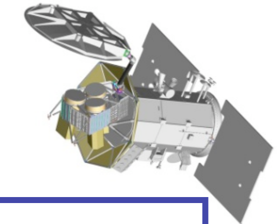
The uncertainties in mean precipitation data sets are significant.

0.5 m/yr equates to 0.25 psu/yr for H=70m

This is about a factor of 10 greater than the observed SSS trends.

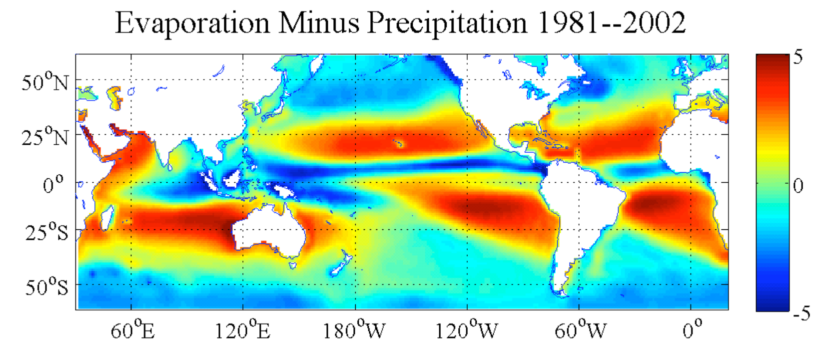
The ocean 'rain gage' can detect much smaller E-P changes than the current atmospheric estimates can detect.

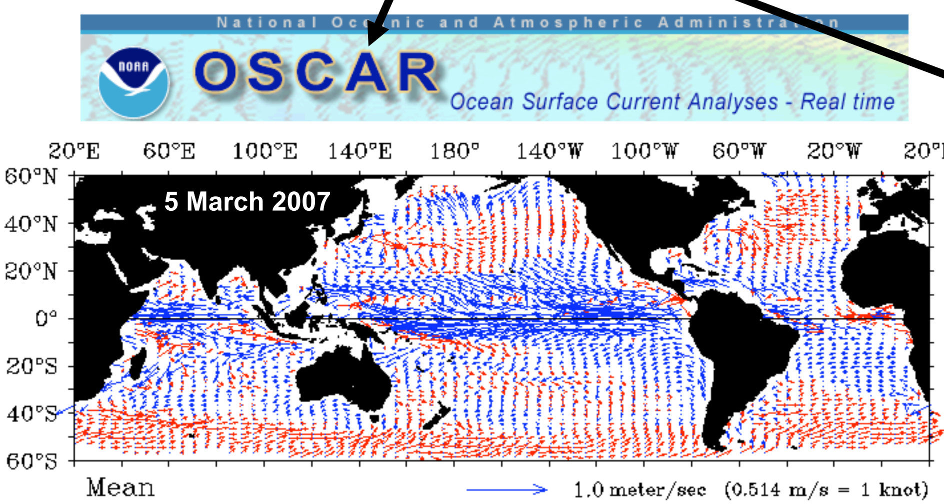
AQUARIUS/SAC-D Preliminary Salt Balance Estimate

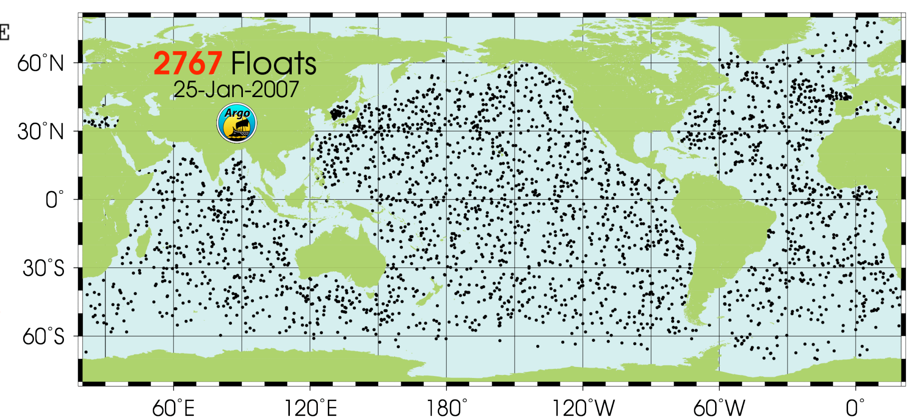


- To examine mean salt (SSS) advection and divergence
- Contrast with SST advection and divergence
- *Trial balance* with E-P net surface freshwater forcing

$U \cdot \nabla S \sim S(E-P)/H$



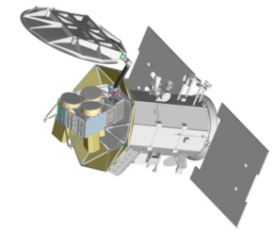


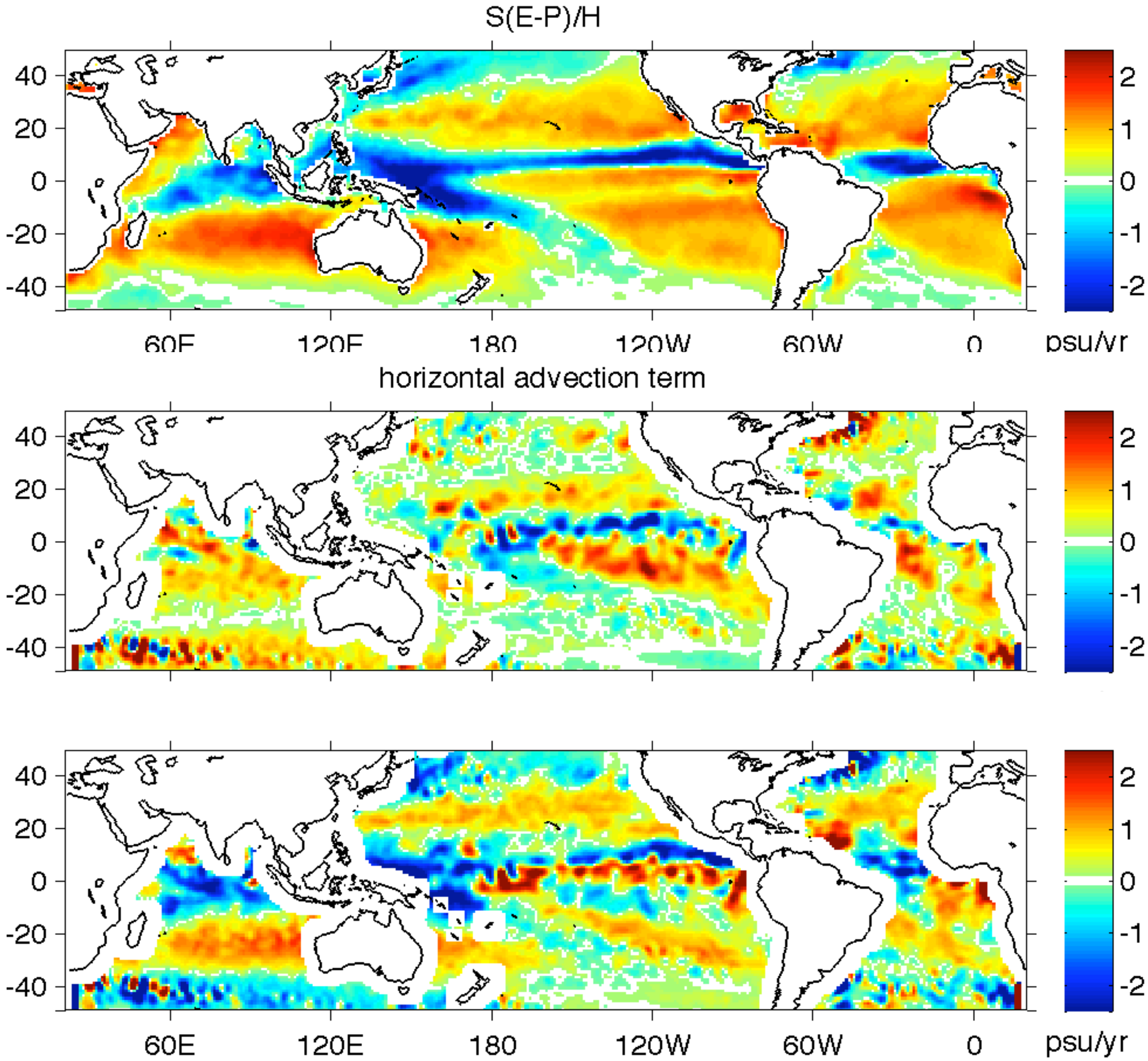


OSCAR = Geostrophic + Ekman @ 15m

AQUARIUS/SAC-D

Trial Balance, 2006 Annual Mean





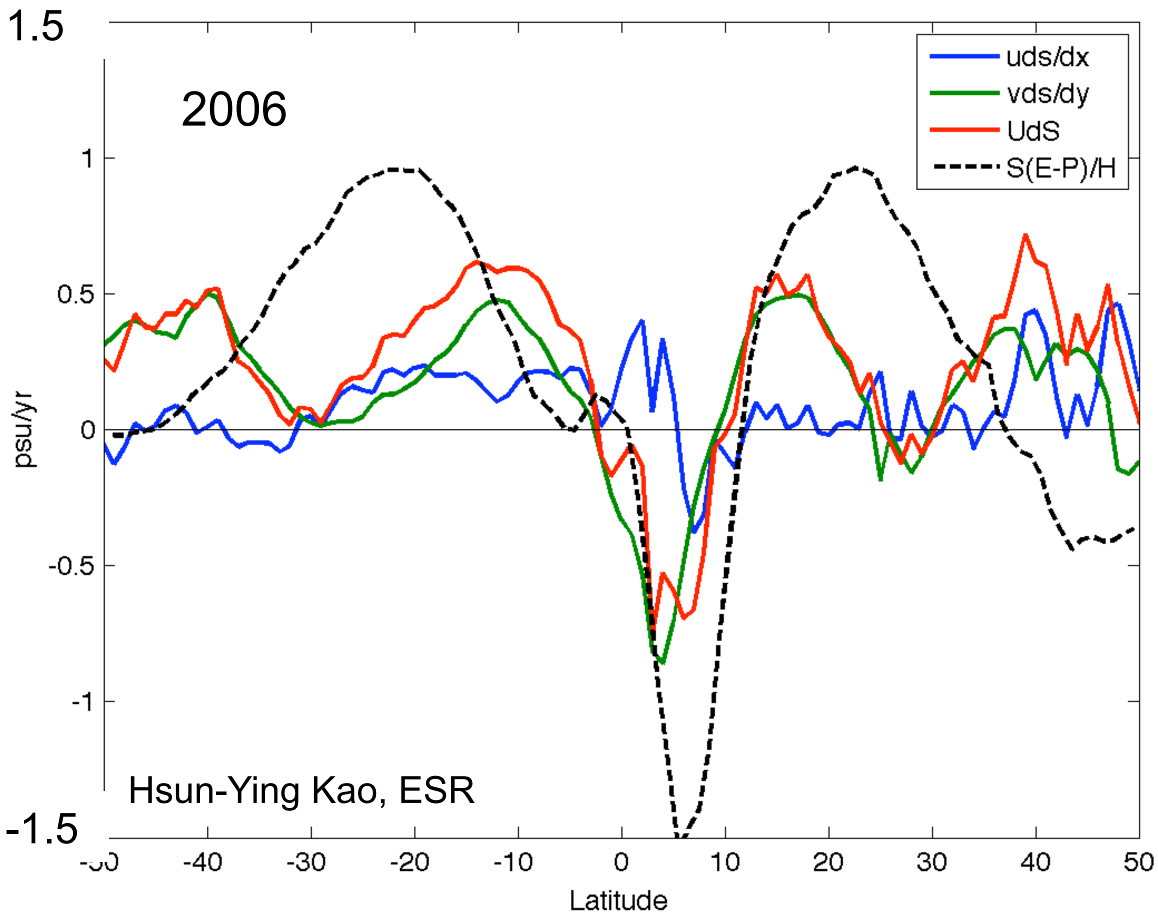
S(E-P)/H
psu · year^{-1}

U·∇S
psu · year^{-1}

S(E-P)/H - U·∇S
psu · year^{-1}

Hsun-Ying Kao, ESR
G. Lagerloef, Aquarius PI

Zonal Averages



Surface advection plays an important role in the freshwater budget.

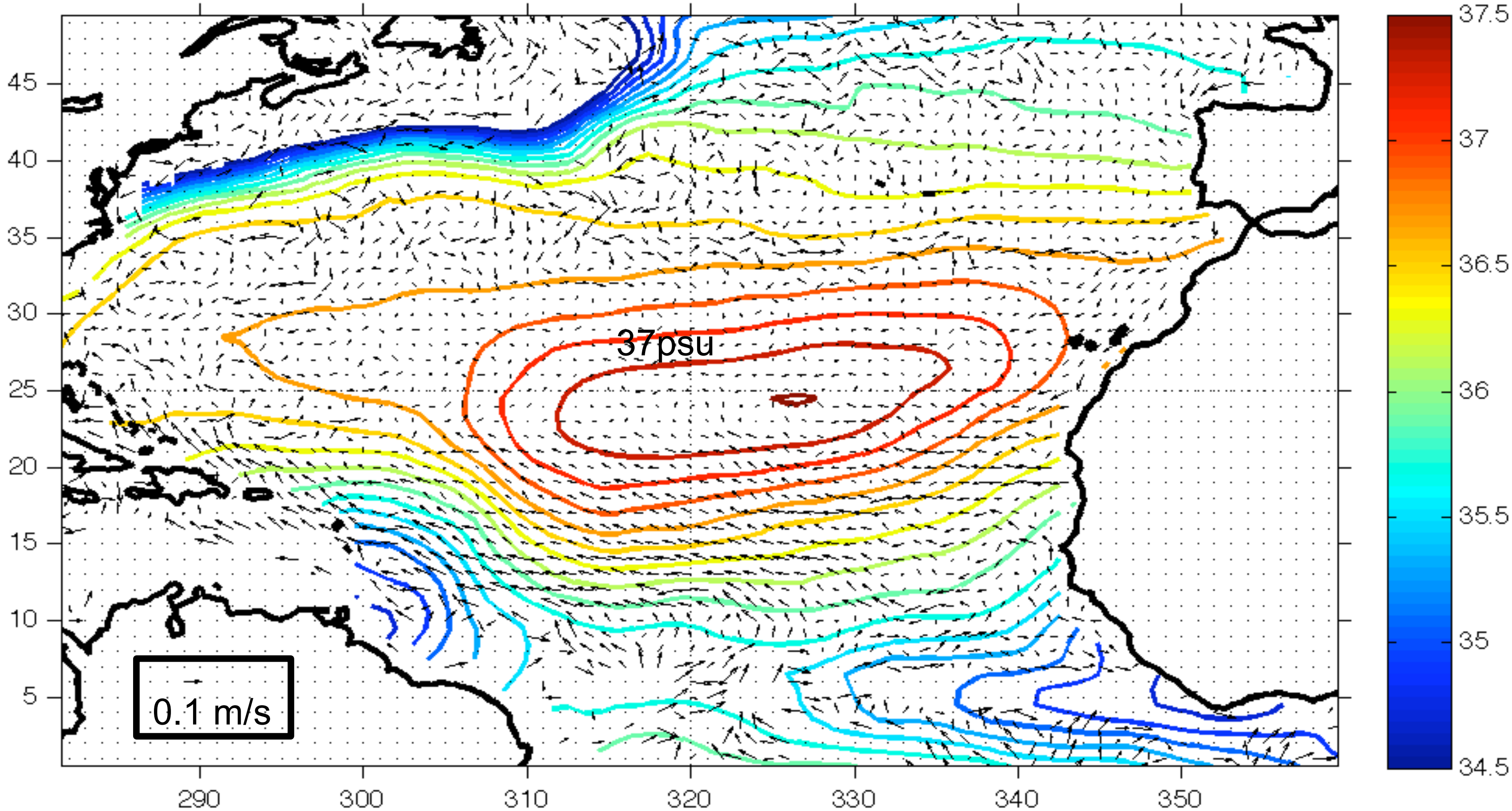
Terms are of similar magnitude

The differences are on the same scale or larger than the precipitation uncertainly ~ 0.25 psu/yr

Differences in mid and high latitudes show where vertical mixing, subduction and other processes are important.

We must resolve these upper ocean processes to close the freshwater budget

North Atlantic Salinity Maximum Salt Balance



$$h\frac{\partial\langle S\rangle}{\partial t} = -h\langle\vec{u}\rangle\bullet\nabla\langle S\rangle - \nabla\bullet\int_{-h}^{0}\hat{\vec{u}}\hat{S}dz - (\langle S\rangle - S_{-h})\left(\frac{\partial h}{\partial t} + \vec{u}_{-h}\bullet\nabla h + w_{-h}\right) + (E-P)S_0 + SSM$$

AQUARIUS/SAC-D

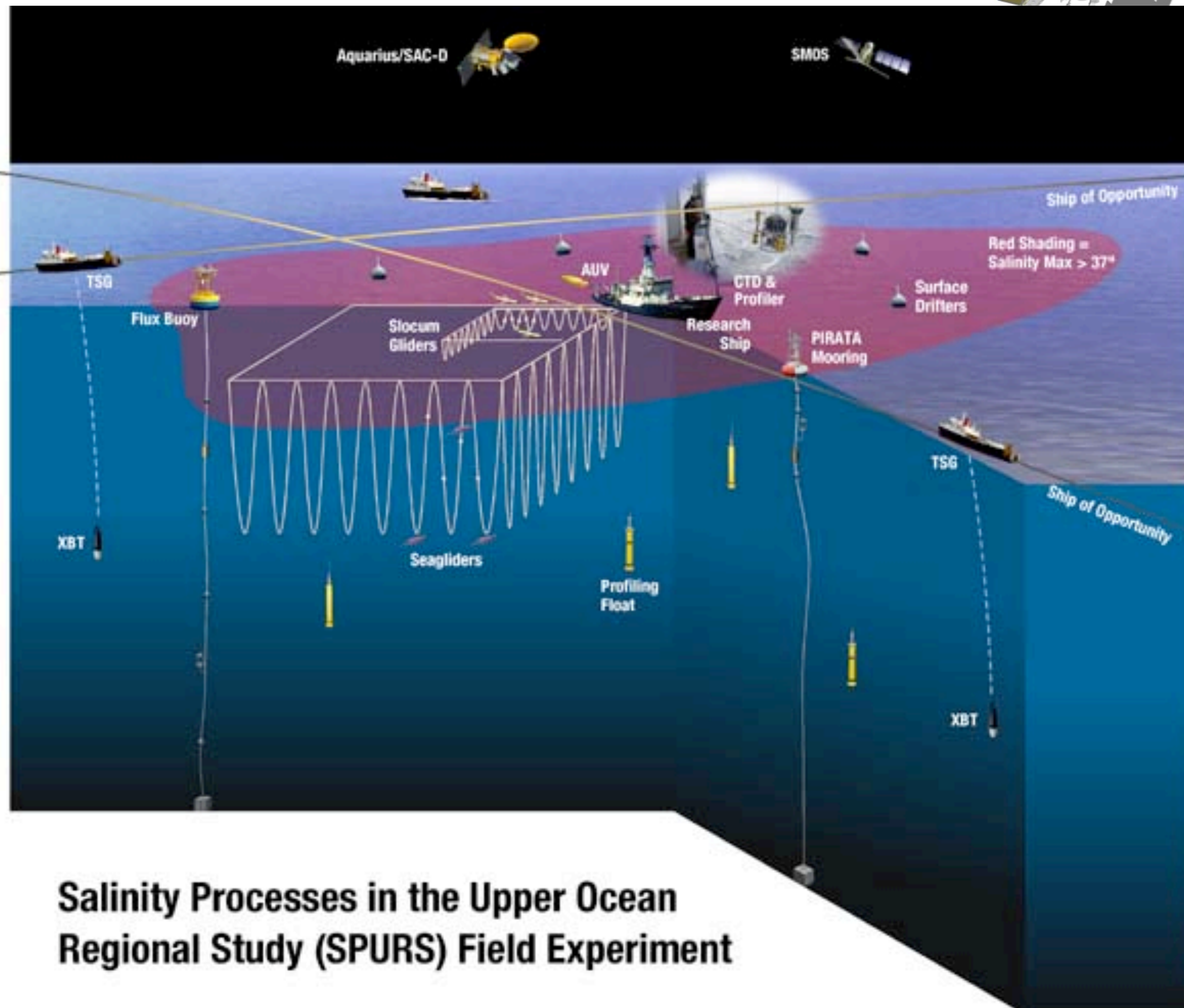
SPURS Field Experiment - 2012

Some Key Questions:

1. What are the physical processes responsible for the location, magnitude and maintenance of the subtropical Atlantic sea surface salinity maximum?

2. How will the ocean respond to changes in thermal and freshwater forcing associated with a changing climate?

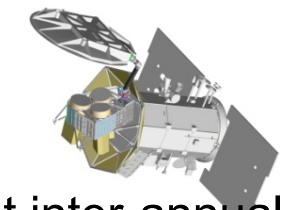
3. And more….

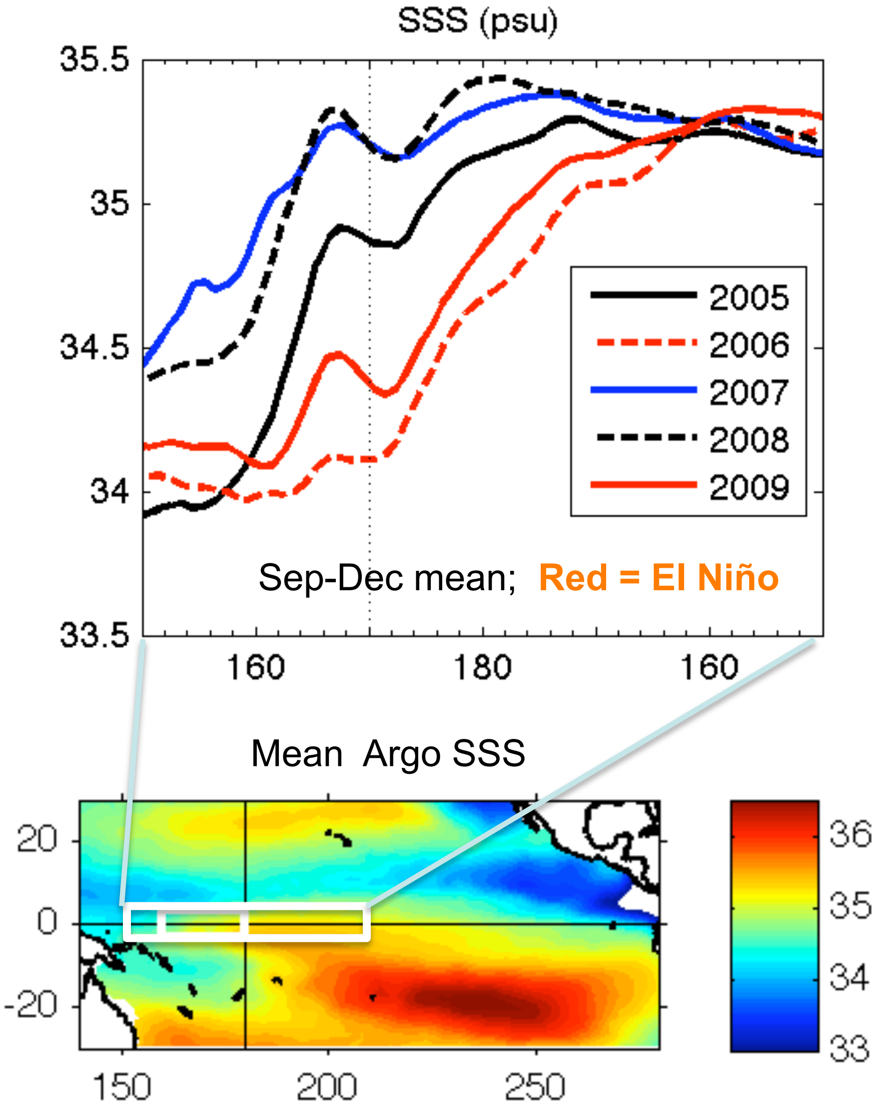


Salinity Processes in the Upper Ocean Regional Study (SPURS) Field Experiment

Website: spurs.jpl.nasa.gov/SPURS/

Recent ENSO SSS Variability





Hsun-Ying Kao, ESR

It is well known that significant inter-annual SSS variations occur in the western Pacific near the eastern edge of the warm pool.

Variations are associated with east-west advection and precipitation.

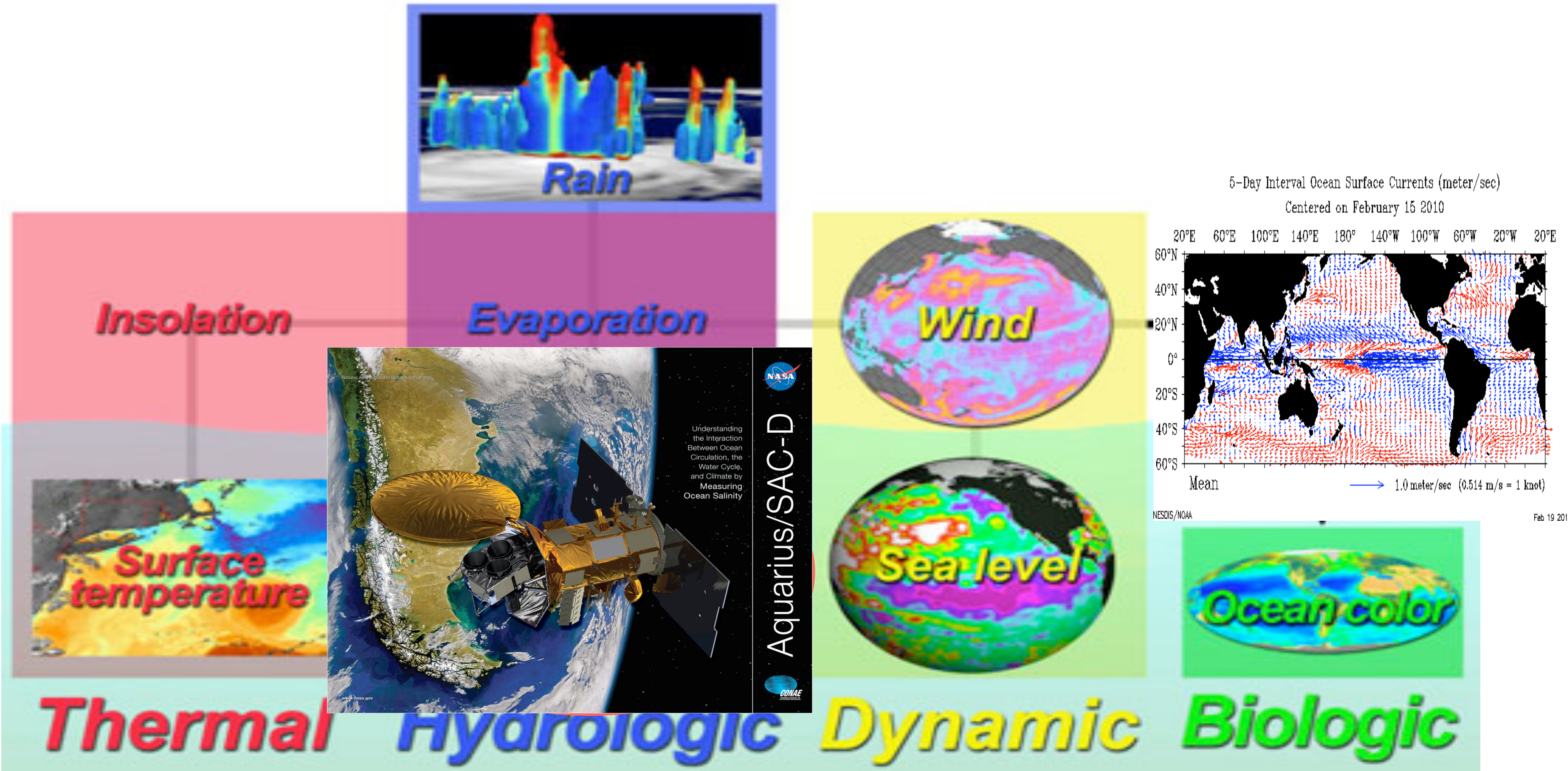
Salinity affects the buoyancy and hence the surface currents, as well as the heat contend associated with dynamic height.

ENSO prediction models need to include salinity as well as temperature data to initialize the ocean state.

The salinity observing system, including salinity on TAO moorings, Argo, and satellite SSS fields are expected to improve ENSO forecast skill.

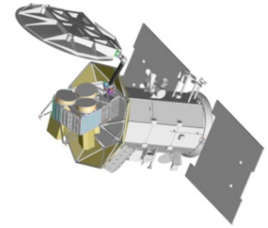
Salinity is the new frontier for ocean remote sensing

Satellites already measure SST, sea level, surface wind, from which we infer ocean circulation, as well as insolation, rain rate, evaporation, and ocean color.



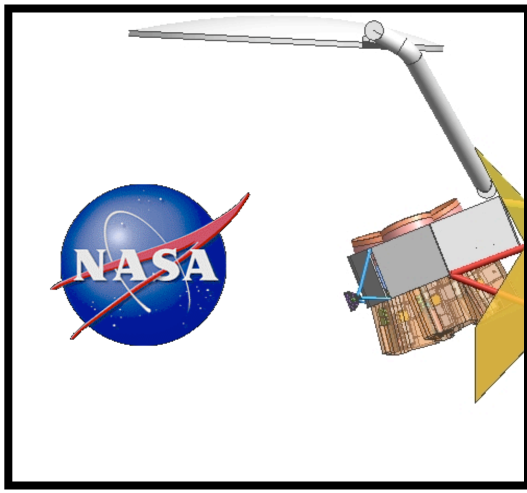
AQUARIUS/SAC-D

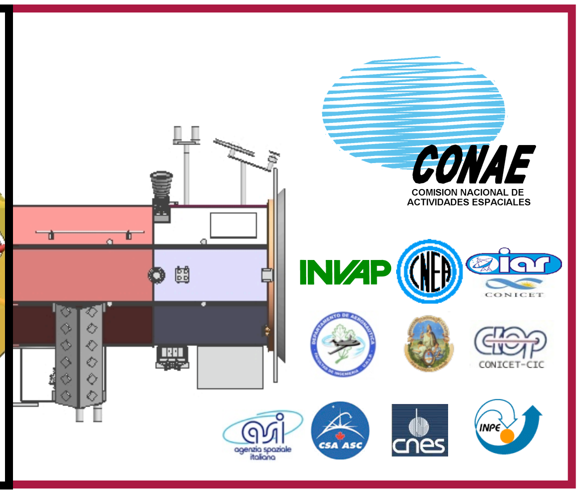
International Partnership



Satellite Observatory

United States – Argentina
and other agencies

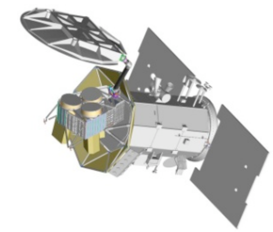




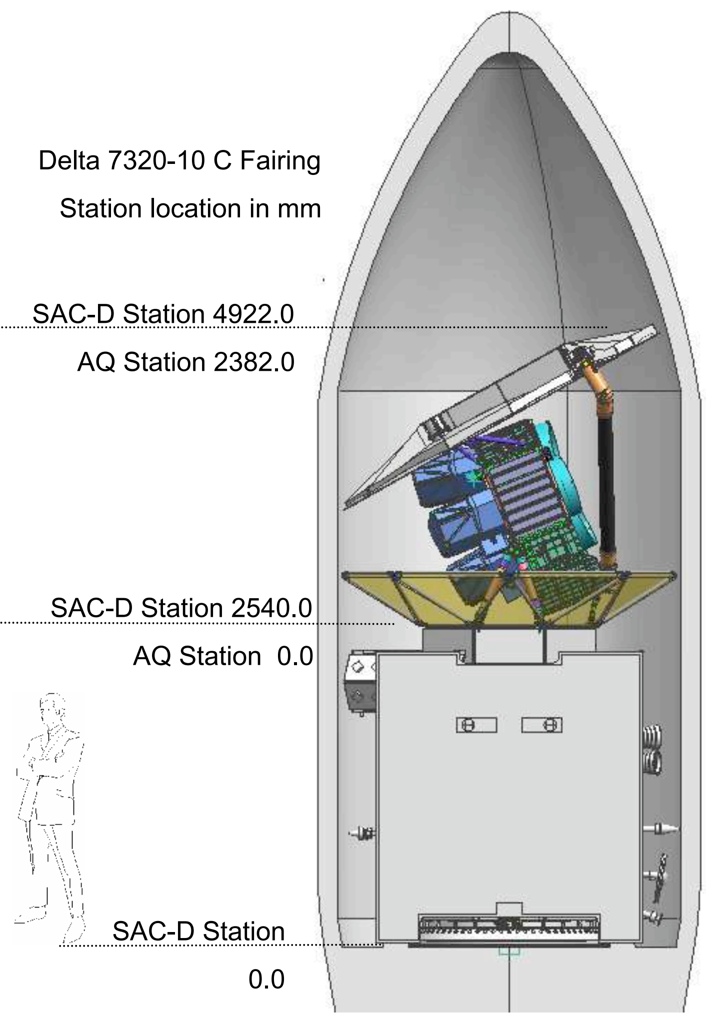
- Aquarius Salinity Microwave Instrument (Instrument Ops + Science Data Processing)
- Launch Vehicle

- Service Platform and SAC-D Science Instruments
- Mission Operations & Ground System

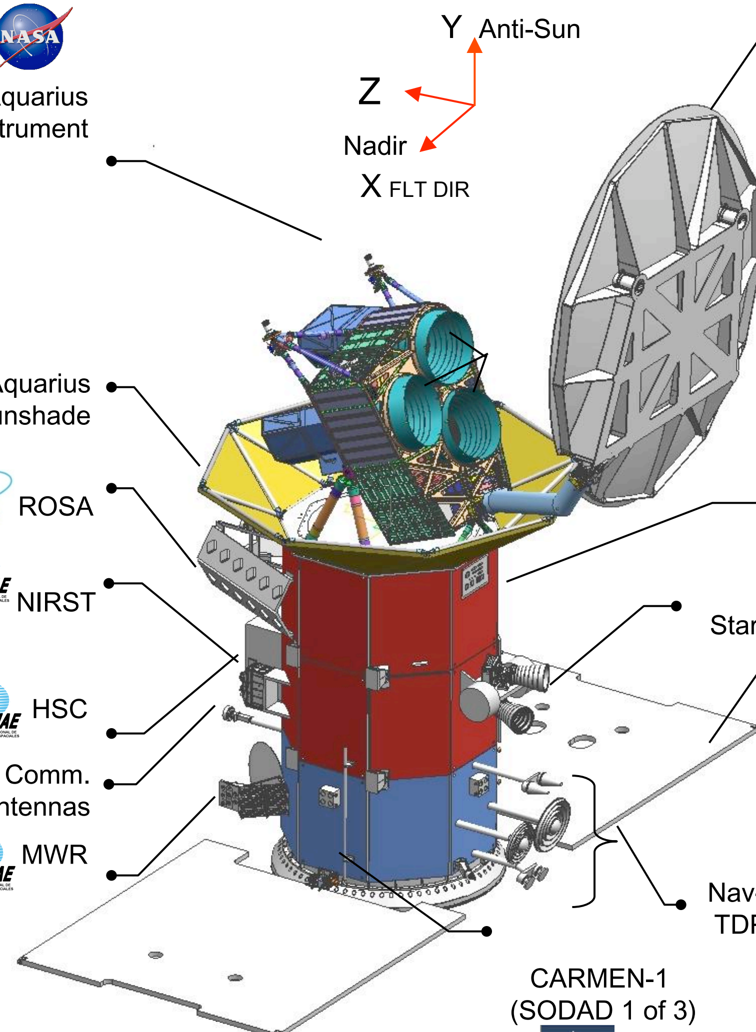
Observatory Configuration

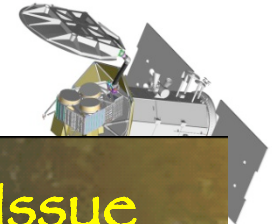


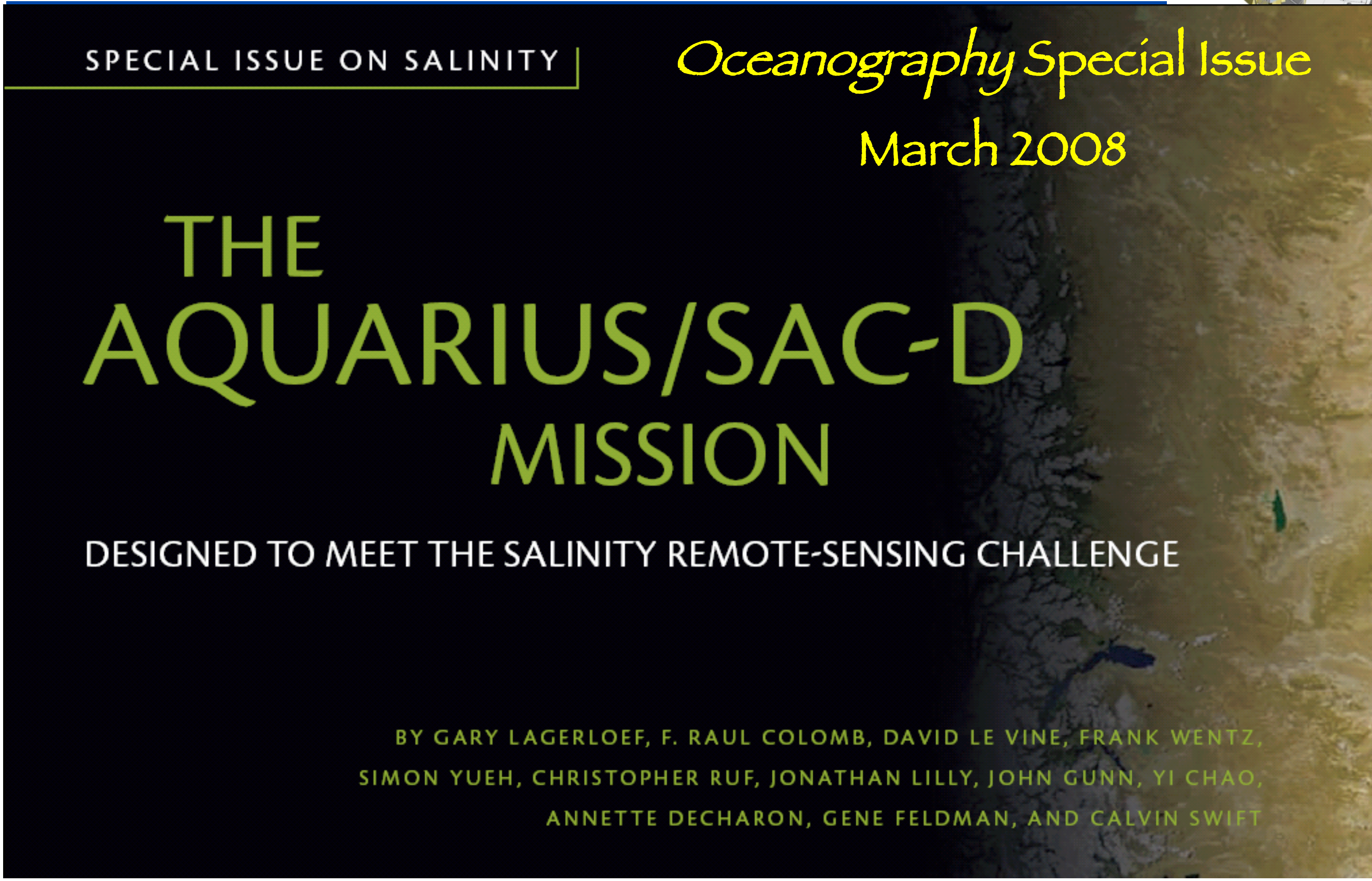
Stowed Configuration



Deployed Configuration







Oceanography Special Issue

March 2008

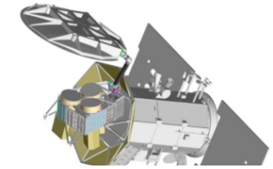
SPECIAL ISSUE ON SALINITY

THE AQUARIUS/SAC-D MISSION

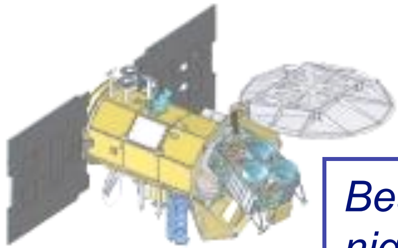
DESIGNED TO MEET THE SALINITY REMOTE-SENSING CHALLENGE

BY GARY LAGERLOEF, F. RAUL COLOMB, DAVID LE VINE, FRANK WENTZ, SIMON YUEH, CHRISTOPHER RUF, JONATHAN LILLY, JOHN GUNN, YI CHAO, ANNETTE DECHARON, GENE FELDMAN, AND CALVIN SWIFT

Mission Design and Sampling Strategy



Sun-synchronous exact repeat orbit
6pm ascending node
Altitude 657 km

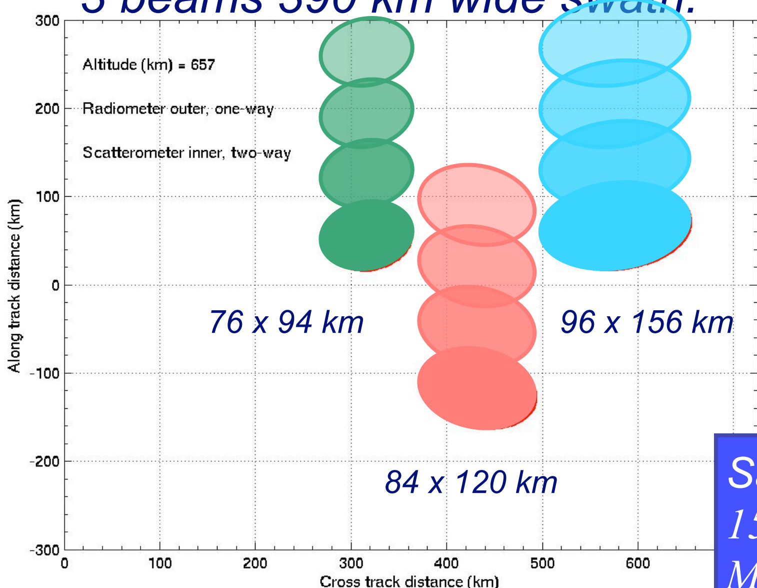


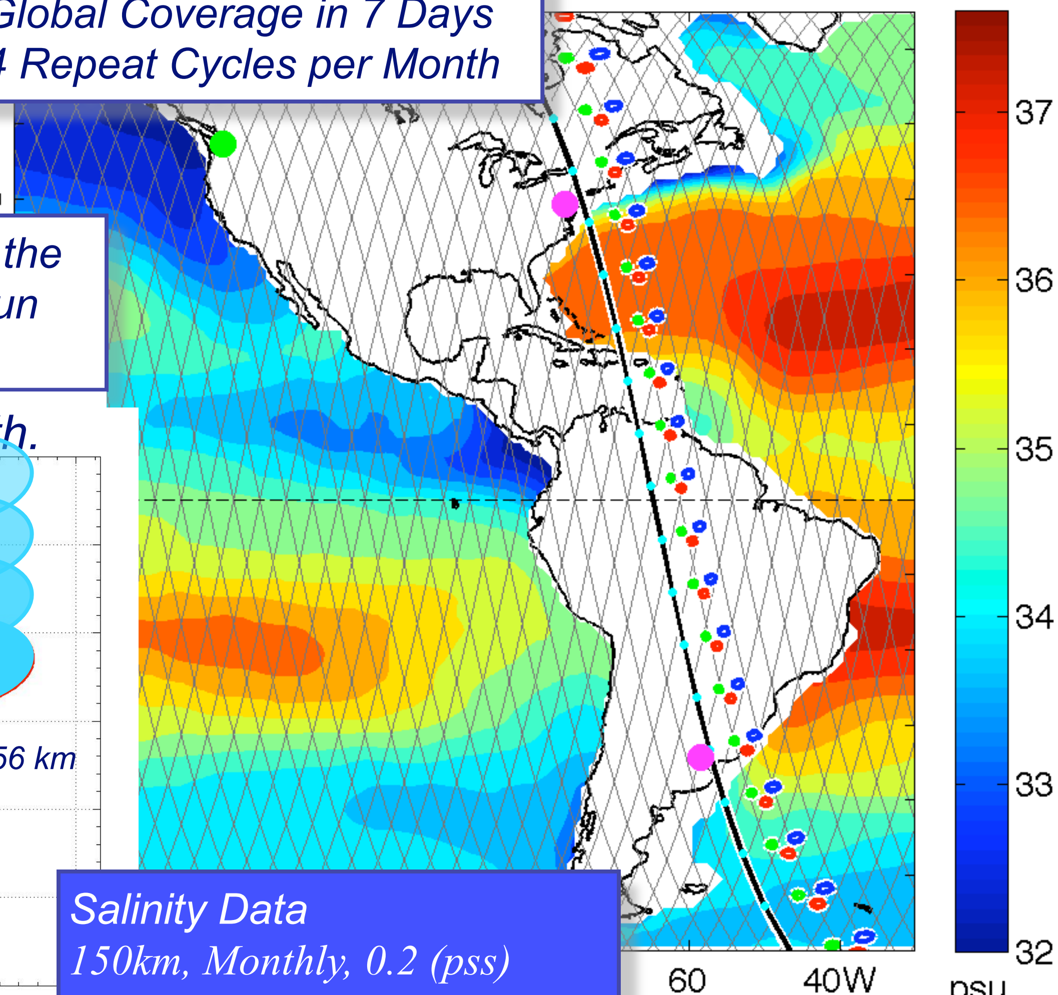
- *Global Coverage in 7 Days*
- *4 Repeat Cycles per Month*

Beams point toward the night side to avoid sun glint

In Orbit Check out

3 beams 390 km wide swath.

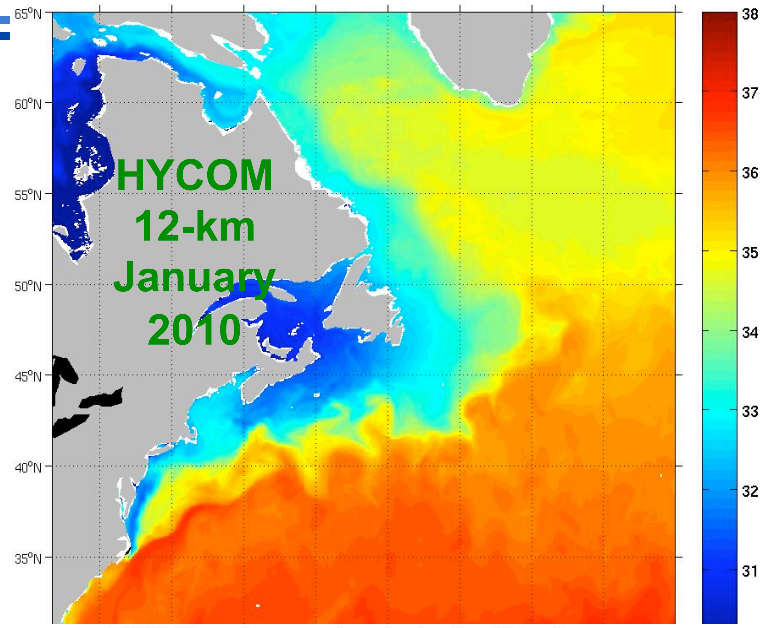


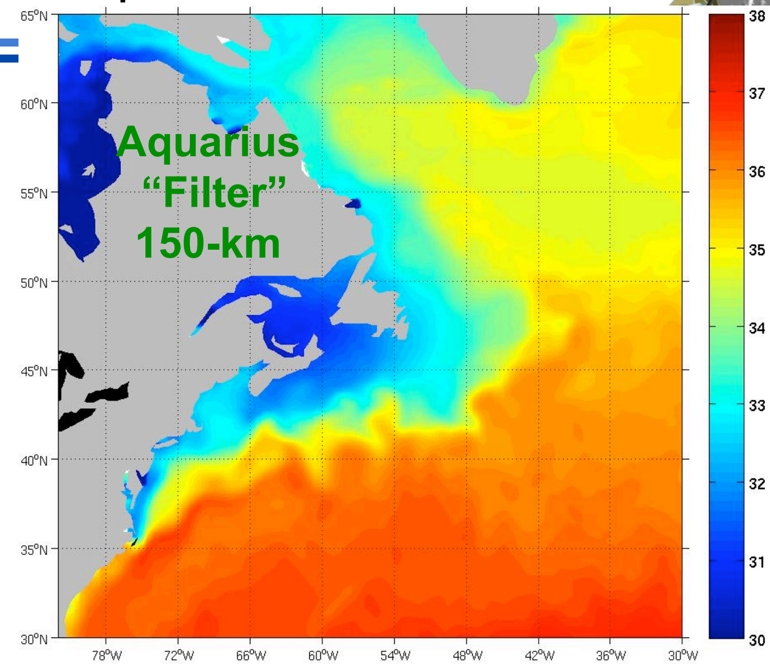


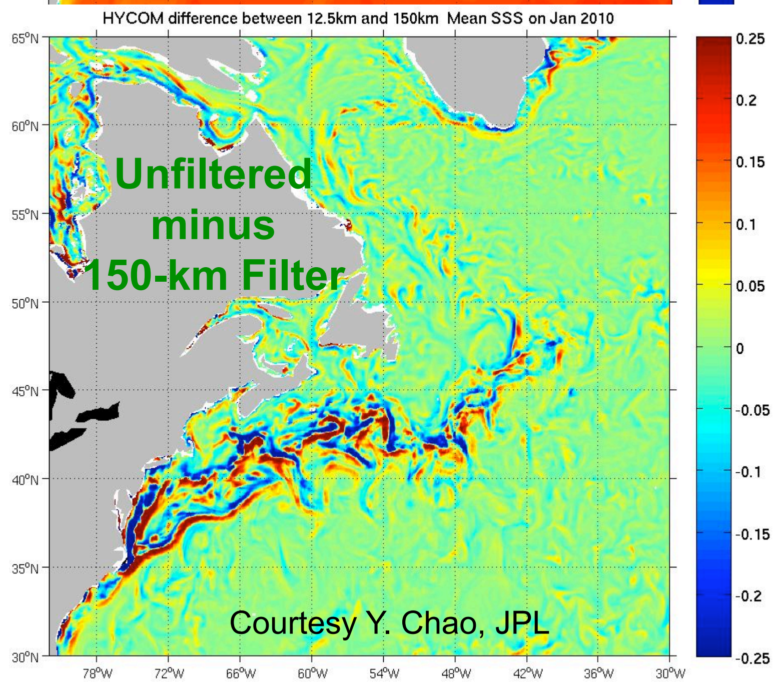
Launch 2010

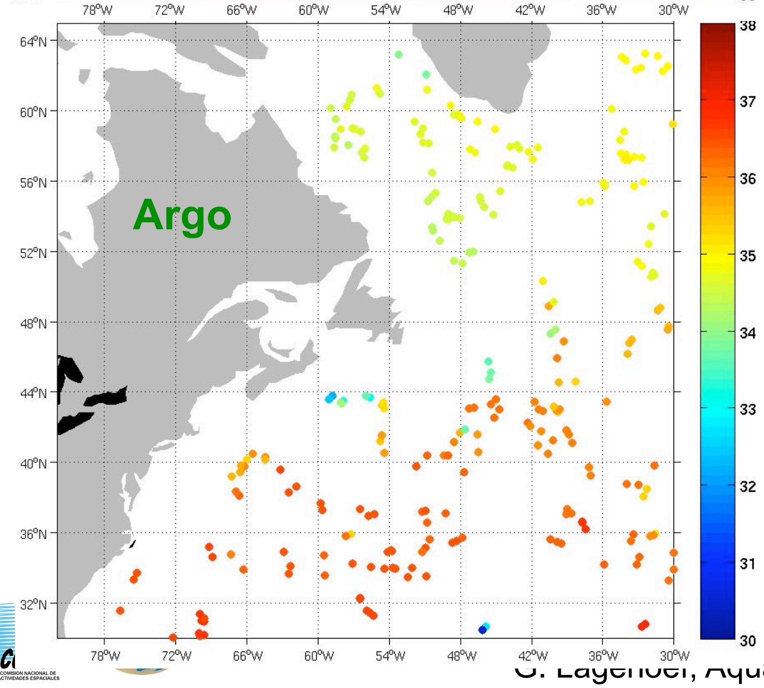
Salinity Data
150km, Monthly, 0.2 (pss)
Mission Requirement

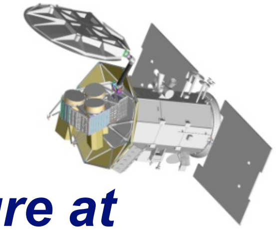
AQUARIUS/SAC-D Aquarius 150 km spatial resolution











Salinity is Derived by Measuring Brightness Temperature at L-Band (1.413 GHz)

Microwave radiometers measure the emitted power of a surface in terms of a parameter called the radiometric brightness temperature (T_B), which is proportional to the ideal black body radiation.

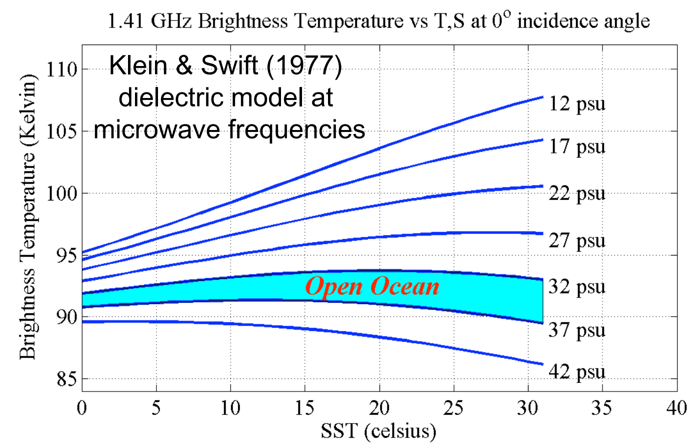
T_B is the product of emissivity (e) and absolute surface temperature (T) in Kelvins

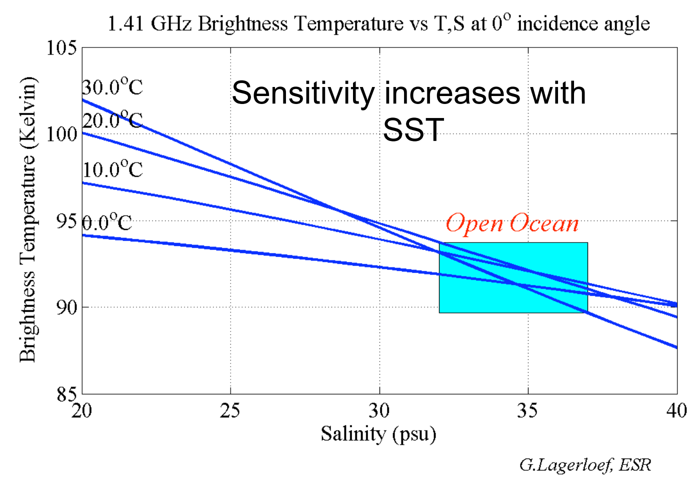
T_B=eT, where e~0.3 for seawater

e is a function of, incidence angle θ, polarization H or V, sea state and the dielectric coefficient ε.

ε depends on **S**, T, and radio frequency (*f*)

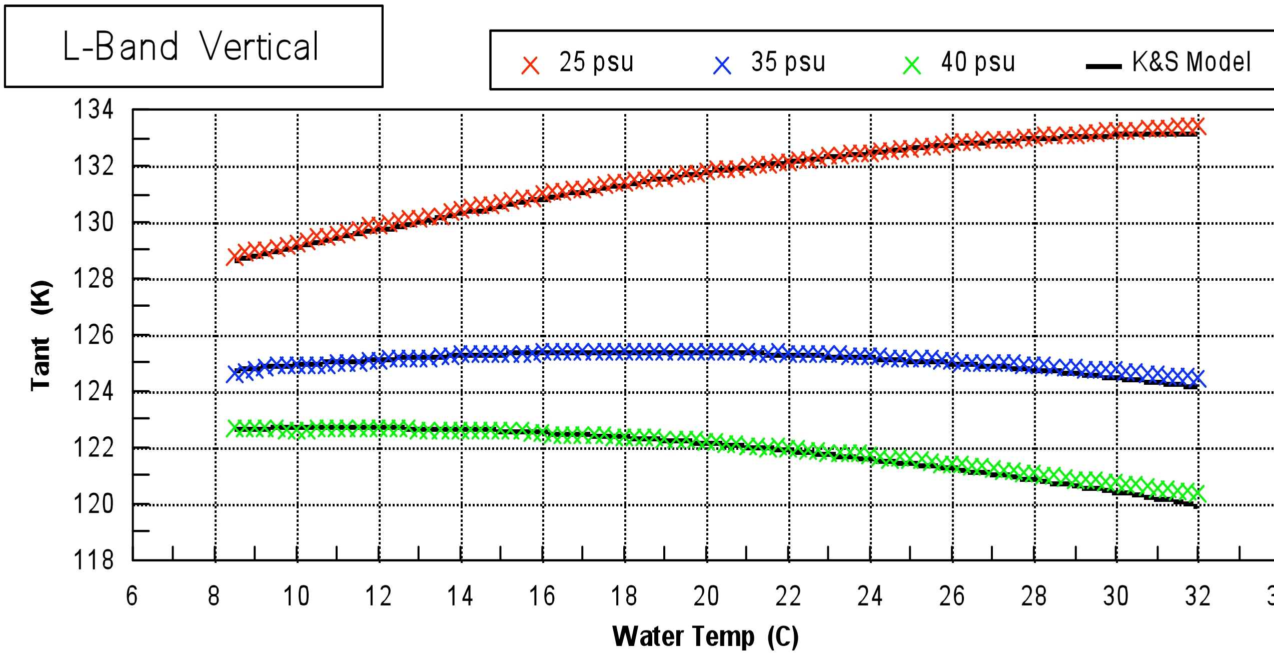
$$\varepsilon = \varepsilon_\infty + \frac{\varepsilon_s(S,T) - \varepsilon_\infty}{1 + i2\pi f \tau(S,T)} - \frac{iC(S,T)}{2\pi f\ \varepsilon_0}$$





Physical Model Verification

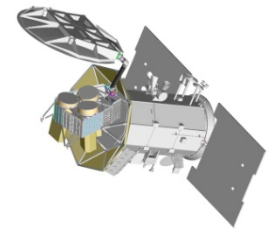
The Aquarius team has validated Klein and Swift theory with controlled experiments over a wide range of temperature & salinity.



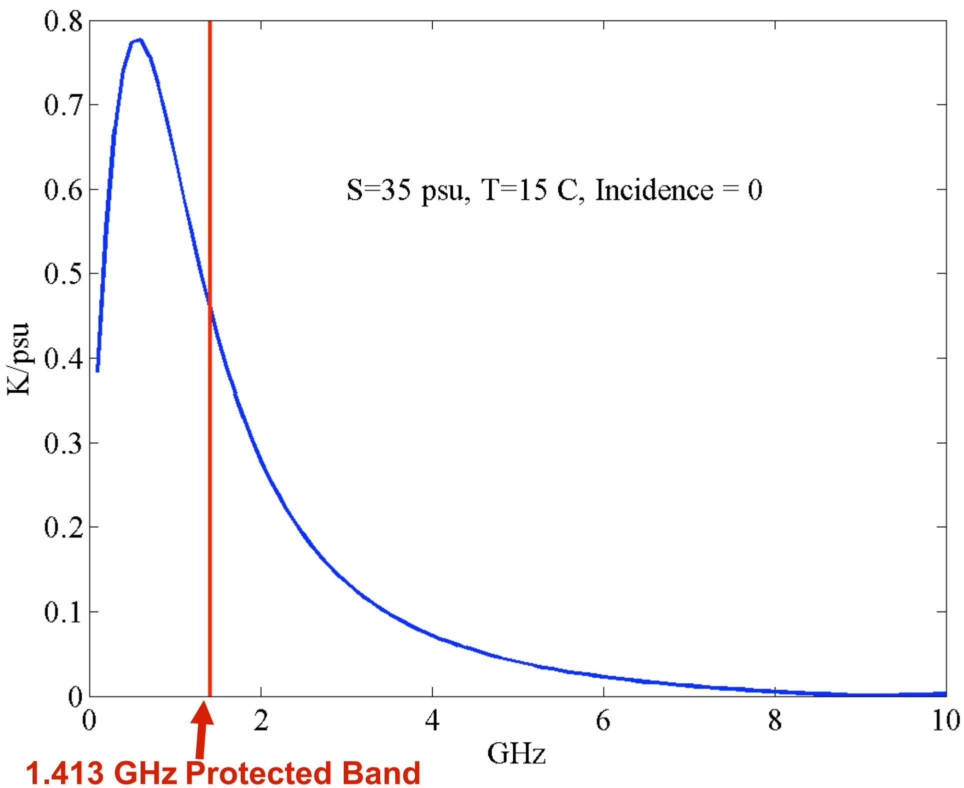
Passive/Active L-/ S-Band Sensor (Wilson and Yueh, JPL, October 2001)

- New laboratory measurements of the sea water dielectric constant at 1.413 GHz are being made.

Why 1.413 GHz?



Sensitivity vs Radiometer Frequency



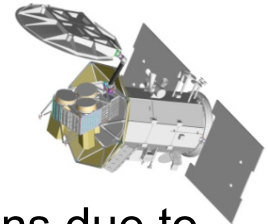
- It is a protected band (radio astronomy)

- Antenna size is manageable. Aquarius will have a 2.5 m antenna to yield a footprint ~100 -150km.

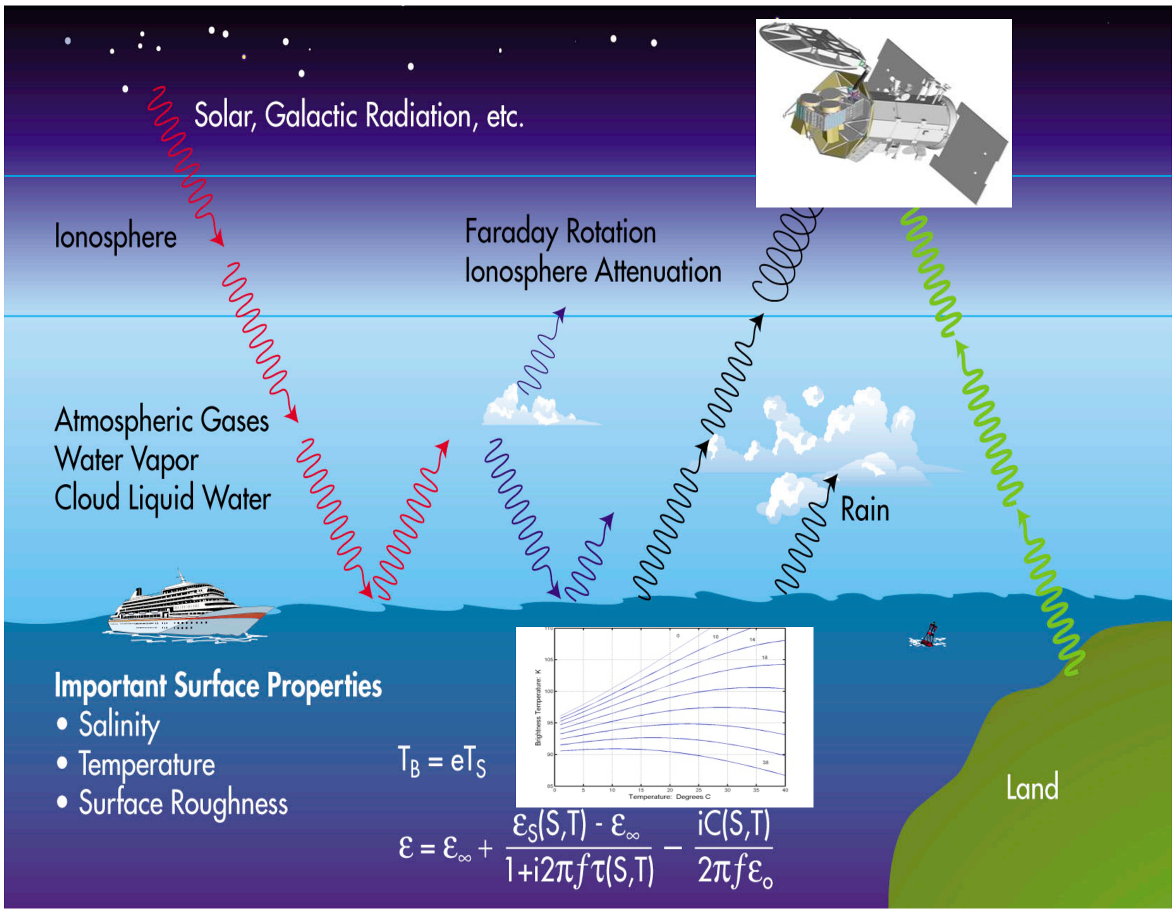
- There is enough sensitivity to detect SSS signatures (~0.1K ≈ 0.2 psu)

- To achieve the required accuracy, the Aquarius radiometers are the most accurate ever developed for satellite.

Steps in Science Retrieval



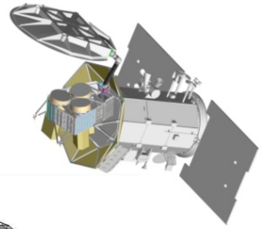
In addition to the surface 'flat sea' emission, we must account for corrections due to the sky, atmosphere, ionosphere, land and ice, and <u>especially surface roughness</u>.

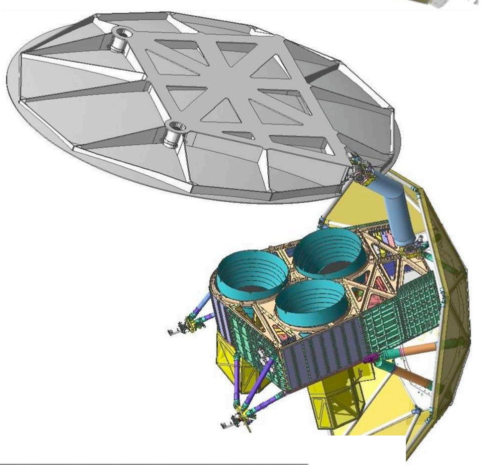


Error Sources	3 Beam RMS Allocation	3 Beam RMS CBE
Radiometer	0.15	0.09
Antenna	0.08	0.01
System Pointing	0.05	0.02
Roughness	0.28	0.20
Solar	0.05	0.02
Galactic	0.05	0.004
Rain (Total Liquid Water)	0.02	0.01
Ionosphere	0.06	0.043
Atmosphere - other	0.05	0.02
SST	0.10	0.07
Antenna gain near land & ice	0.10	0.10
Model Function	0.08	0.07
Brightness Temperature Error per Observation	**Baseline Mission** Allocation	CBE
Total RSS (K)	0.38	0.27
Margin RSS (K)	0.27	

Latitude Range	Mean Sensitivity (dTv/dS)	Mean # Samples in 28 Days	Baseline Mission Monthly Salinity Error (psu) Allocation	CBE
0-10	0.756	10.9	0.15	0.11
11-20	0.731	11.3	0.16	0.11
21-30	0.671	12.1	0.16	0.12
31-40	0.567	13.5	0.18	0.13
41-50	0.455	15.9	0.21	0.15
51-60	0.357	20.3	0.24	0.17
61-70	0.271	30.2	0.26	0.18
Global RMS (psu)			0.20	0.14
Margin RSS (psu)			0.14	

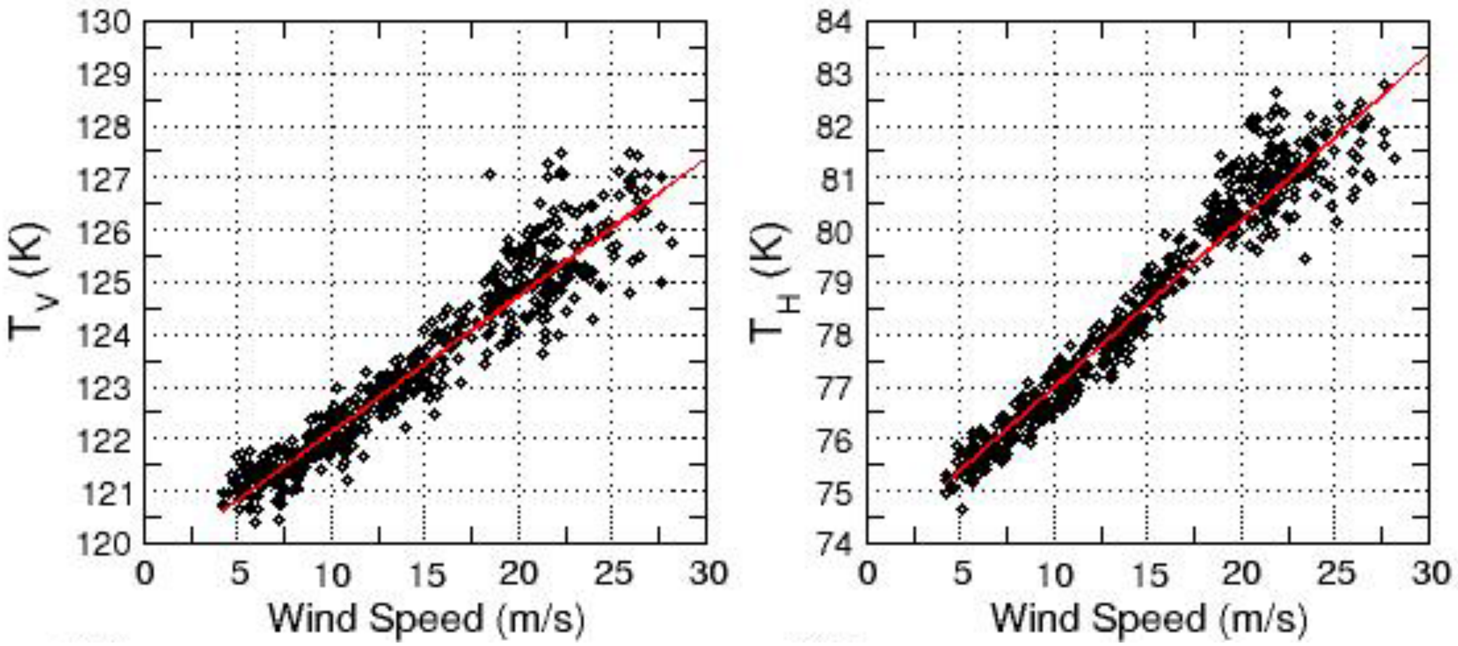
Wind Roughness Correction





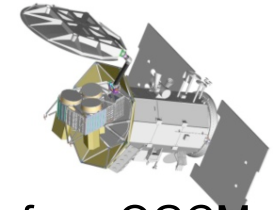
Surface wind roughness is the largest single error source; > 12 psu in high winds

Aquarius includes an integrated radar scatterometer to make simultaneous 'bore sight' measurements to correct this

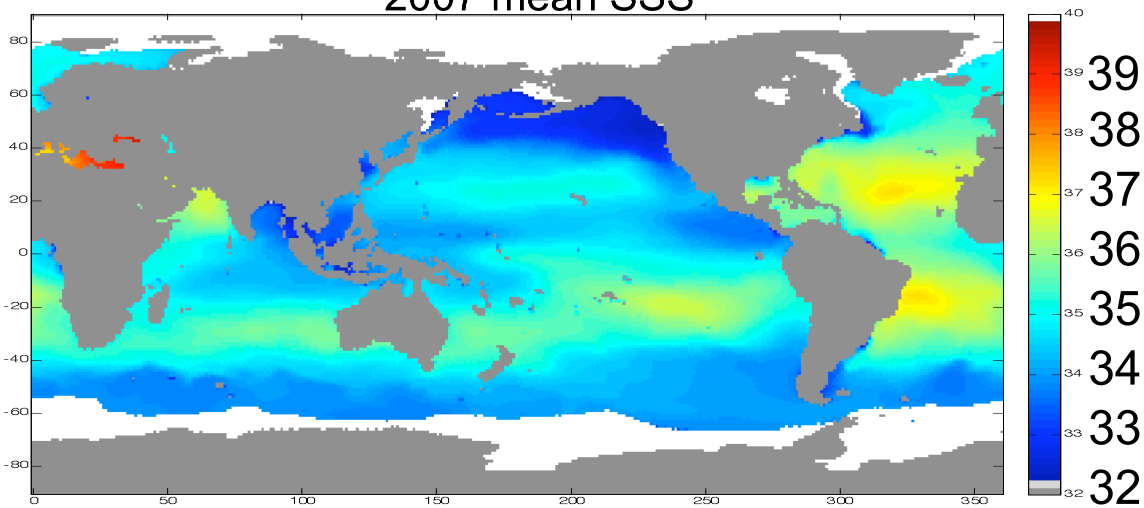


PALS Airborne data, 2009, courtesy of S. Yueh, JPL

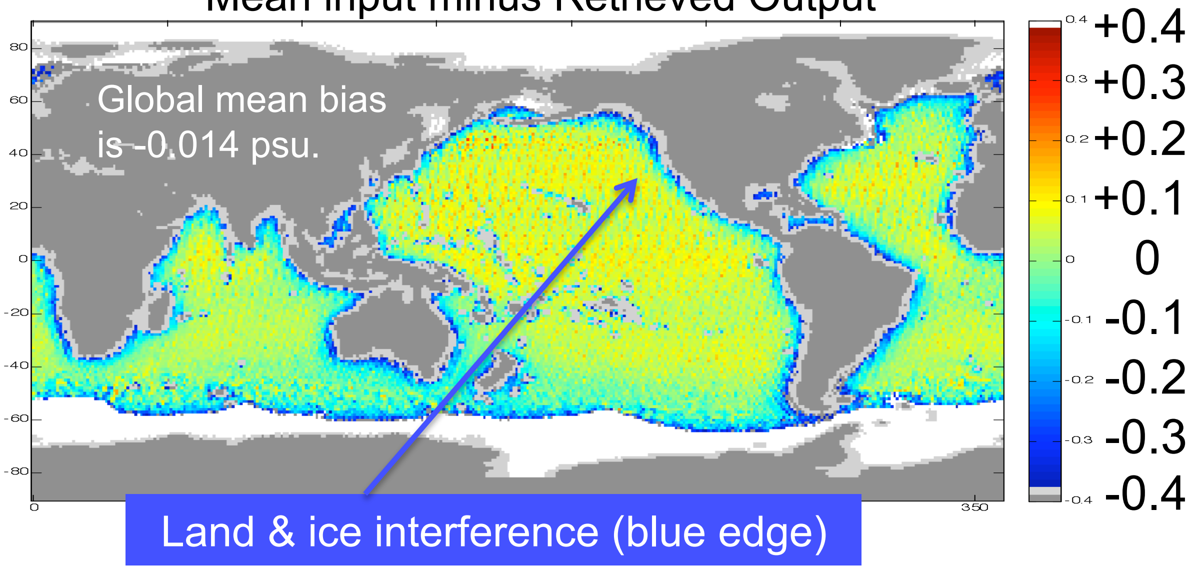
Aquarius Algorithm Simulator



2007 mean SSS



Mean input minus Retrieved Output



Simulate surface Tb from OGCM SSS and SST fields for calendar year 2007 along the satellite orbit swath.

Add the effects of the wind, atmosphere, ionosphere, solar flux, galactic reflection, rain, land and ice brightness temperatures, and the antenna gain.

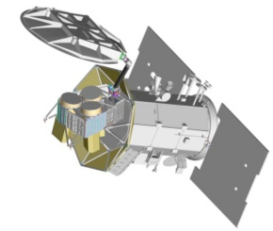
Add realistic errors for wind, SST and instrument noise.

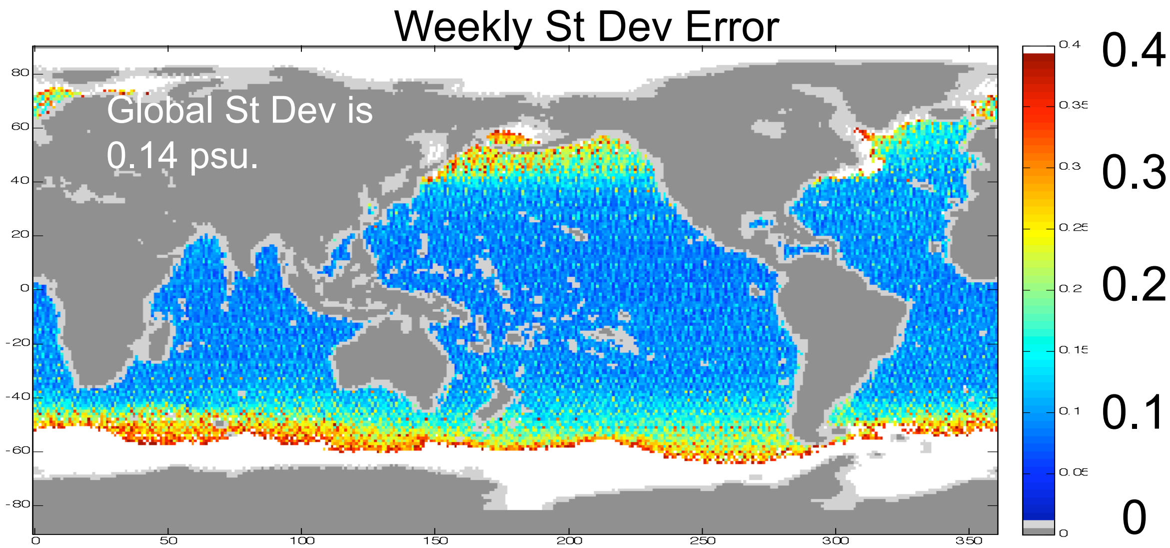
Synthesize the instrument and satellite data telemetry.

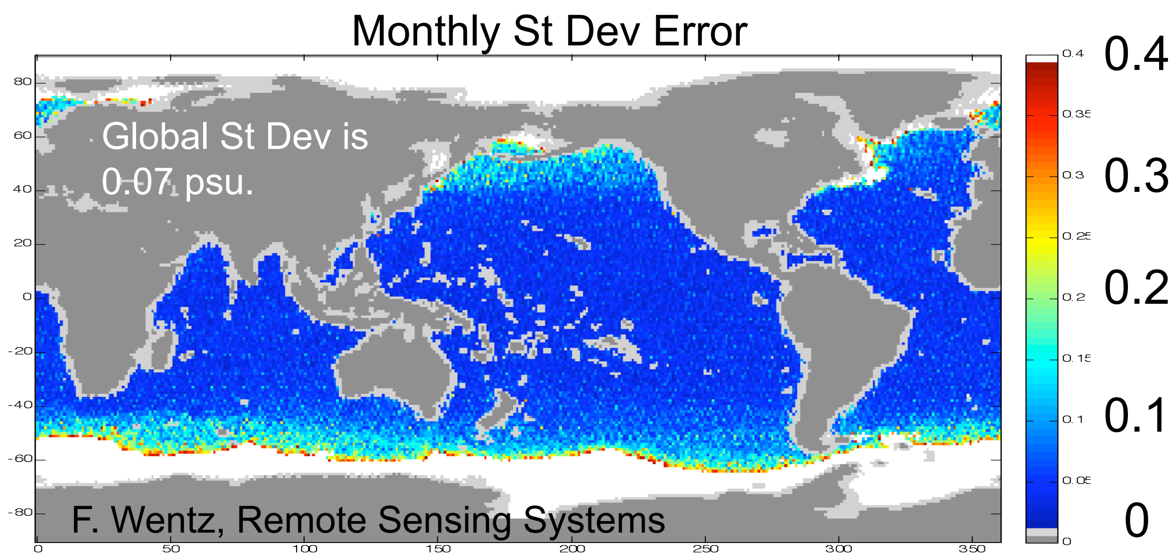
Run the simulated data through the salinity retrieval algorithm, and compare with the OGCM input.

AQUARIUS/SAC-D

Standard Deviation Simulated Error







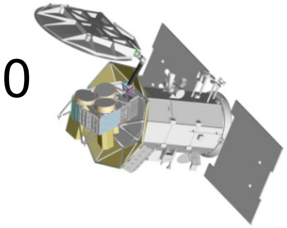
Errors increase toward high latitude (SST effect).

Very favorable results that must be viewed with caution.

Several unknowns are not included in the simulator:

- incomplete roughness model
- antenna gain unknowns
- galactic model error
- galactic reflection off rough surfaces
- heavy rain
- and more…..

AQUARIUS/SAC-D Simulators to be ready in March - April 2010

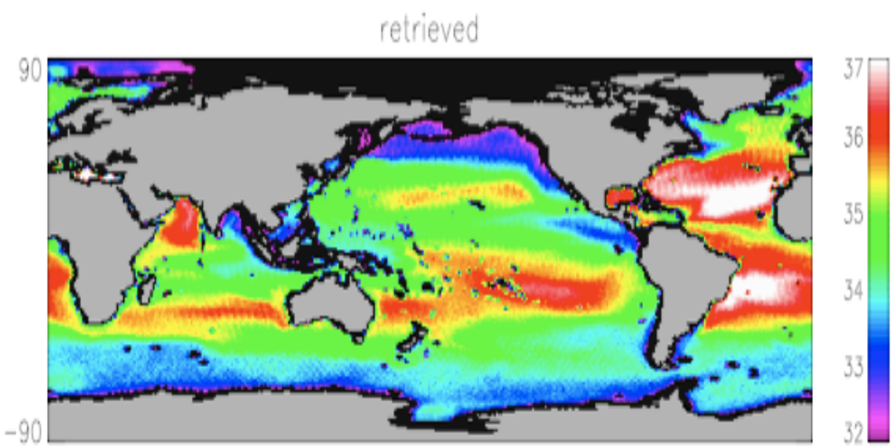


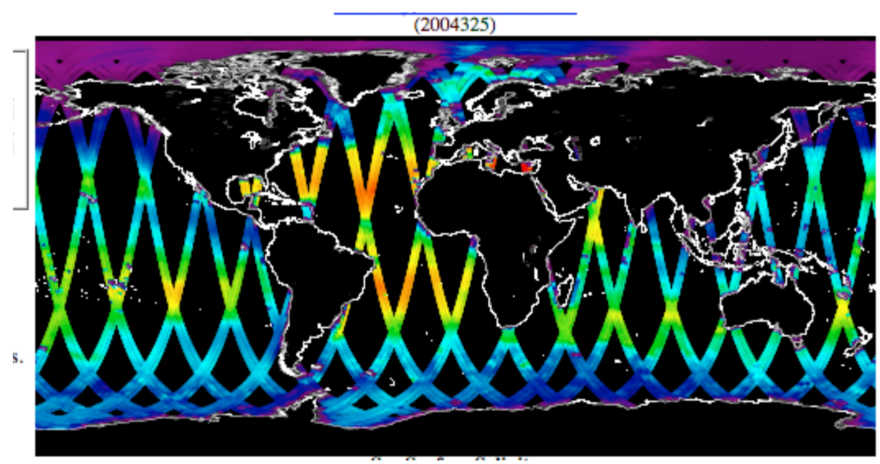
Science Simulator

- New 12-month simulator now being computed for calendar year 2007 ocean
- Will be released as Level 2 science data files.

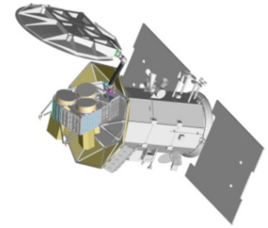
Operational Simulator

- “real time” data processing of simulated data on a daily basis
- Daily data will be released through the Aquarius data website as if the mission were actually flying for science team to analyze.





Some useful information



Aquarius website: http://aquarius.nasa.gov/

- Education and Public Outreach page

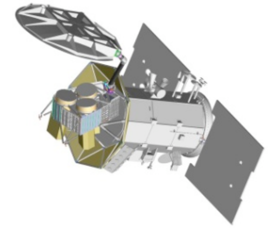
  http://aquarius.nasa.gov/education.html

Upcoming events:

- Aquarius/SAC-D Science Team Meeting, Seattle, 19-21 July 2010
  - Open, with registration required
  - Website will be open in March 2010
  - Agenda will focus on algorithms, calibration and validation in preparation for launch

- NASA/ROSES 2010 announcements of opportunity
  - SPURS
  - Ocean Salinity Science Team – phase 2
  - See http://nspires.nasaprs.com

SMOS Mission



Soil Moisture Ocean Salinity Mission - ESA

Launched November 2009

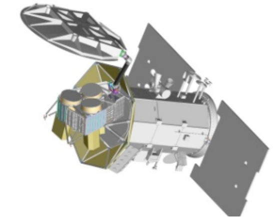
Undergoing six month commissioning phase

Complex 2-D interferometer design

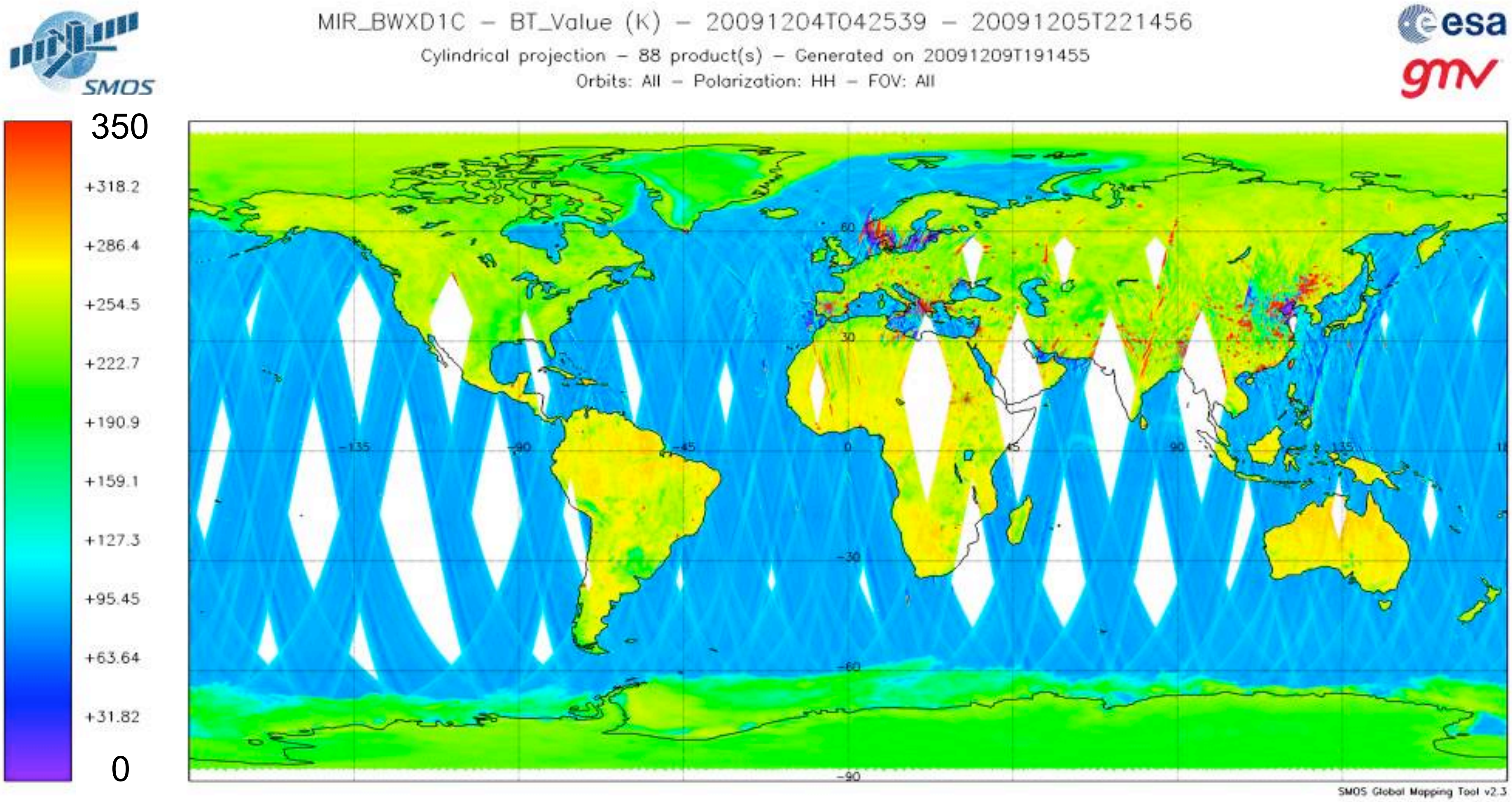
Designed primarily to meet soil moisture science requirements

Some preliminary data generously provided by Y. Kerr and J. Font

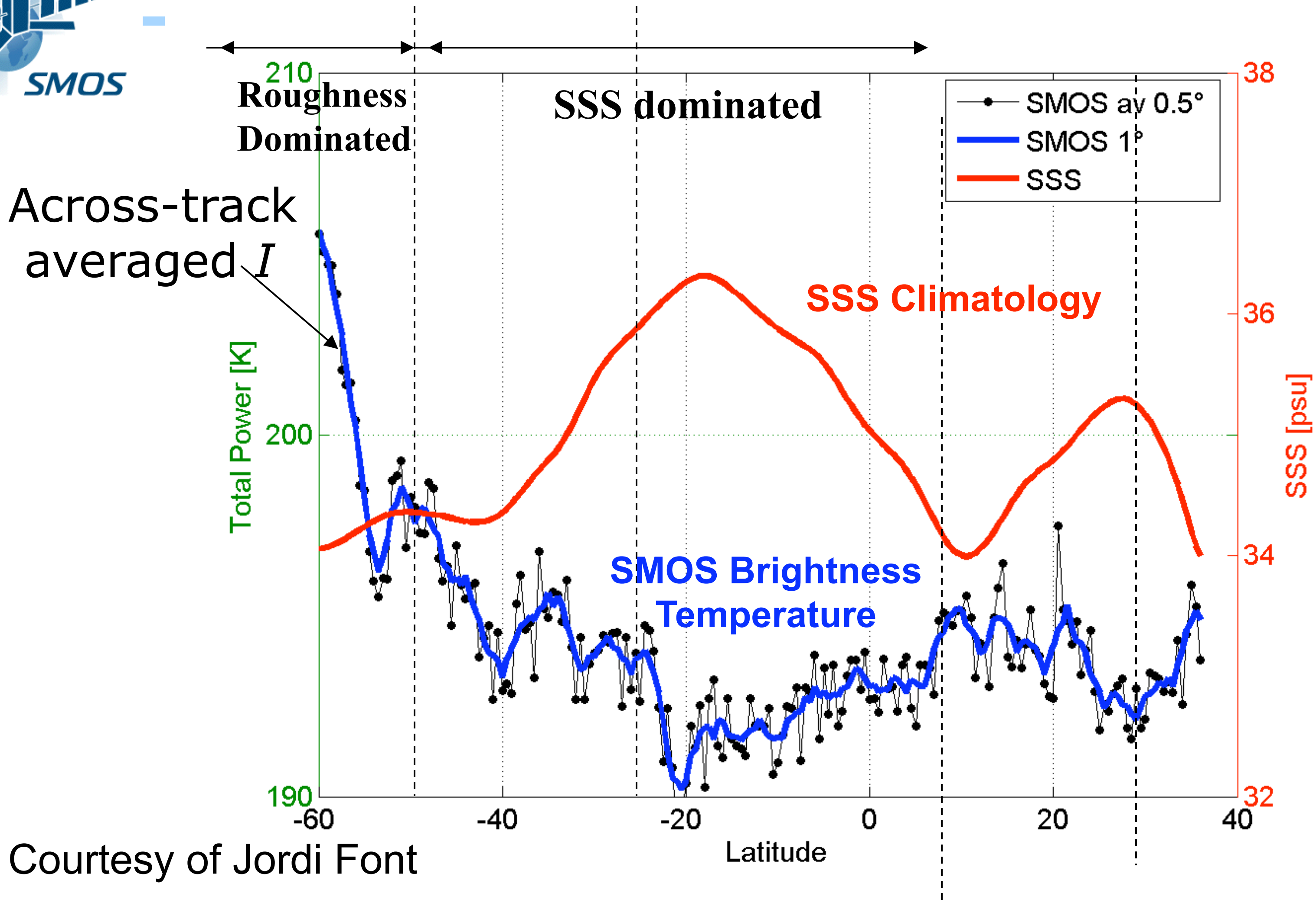
SMOS Brightness Temperature Map



4-5 December 2009

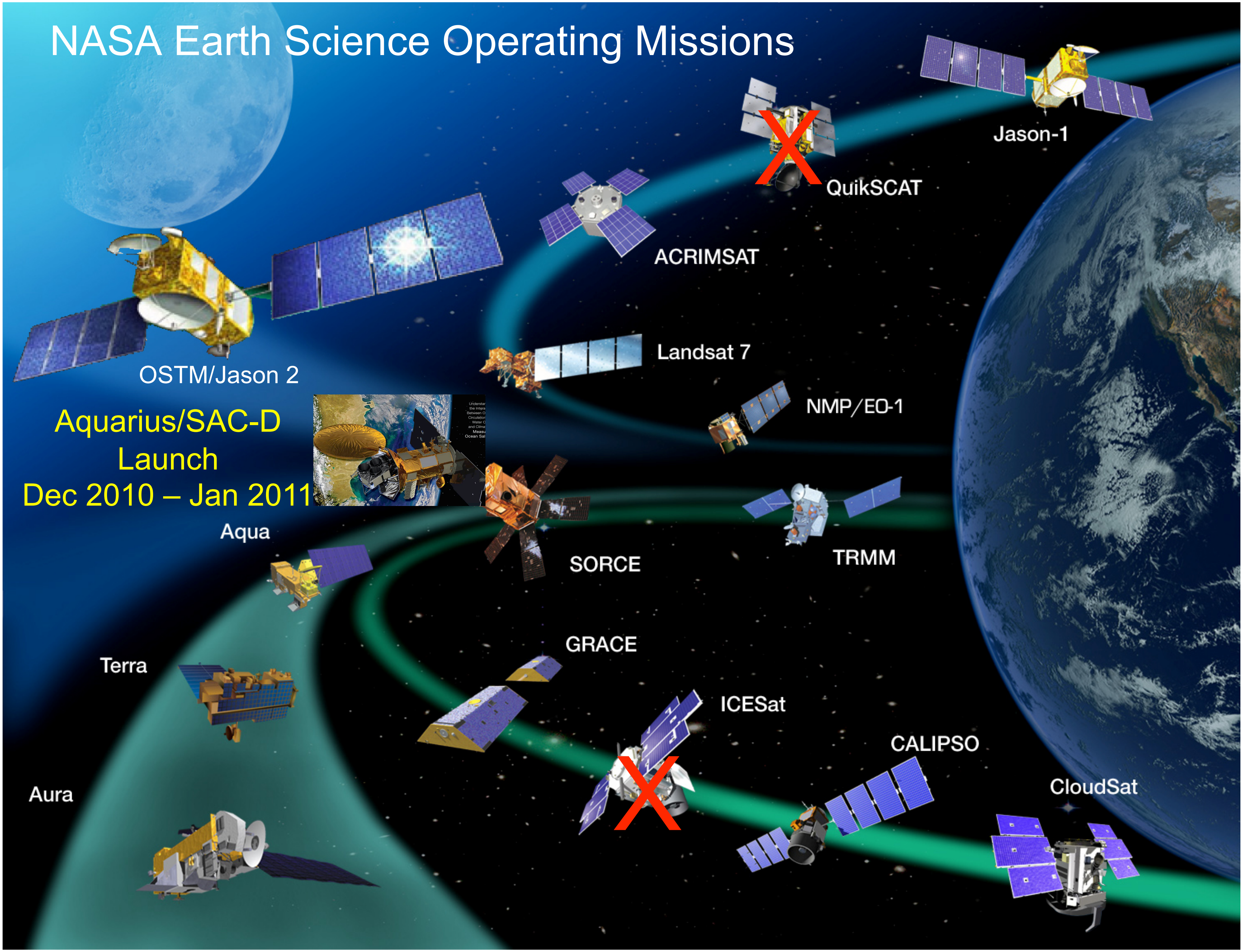


Courtesy of Yann Kerr



Courtesy of Jordi Font

Very clear ~2 psu amplitude large-scale SSS signal signature in SMOS low incidence data (here First Stokes for theta < 5°)

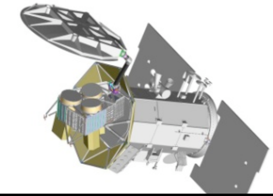

NASA Earth Science Operating Missions
Jason-1
QuikSCAT
ACRIMSAT
OSTM/Jason 2
Landsat 7
NMP/EO-1
Aquarius/SAC-D
Launch
Dec 2010 – Jan 2011
Aqua
SORCE
TRMM
Terra
GRACE
ICESat
CALIPSO
CloudSat
Aura

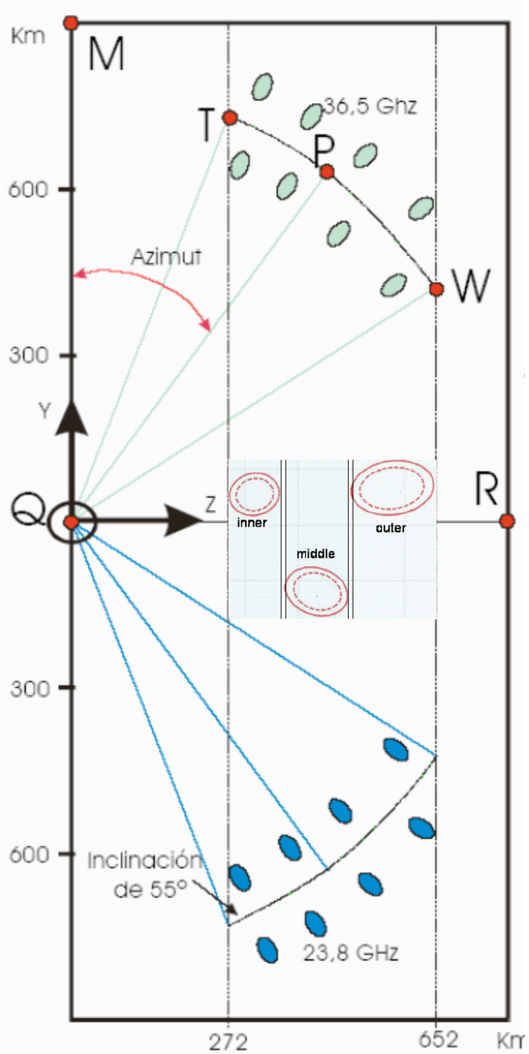
Surface Salinity from Space

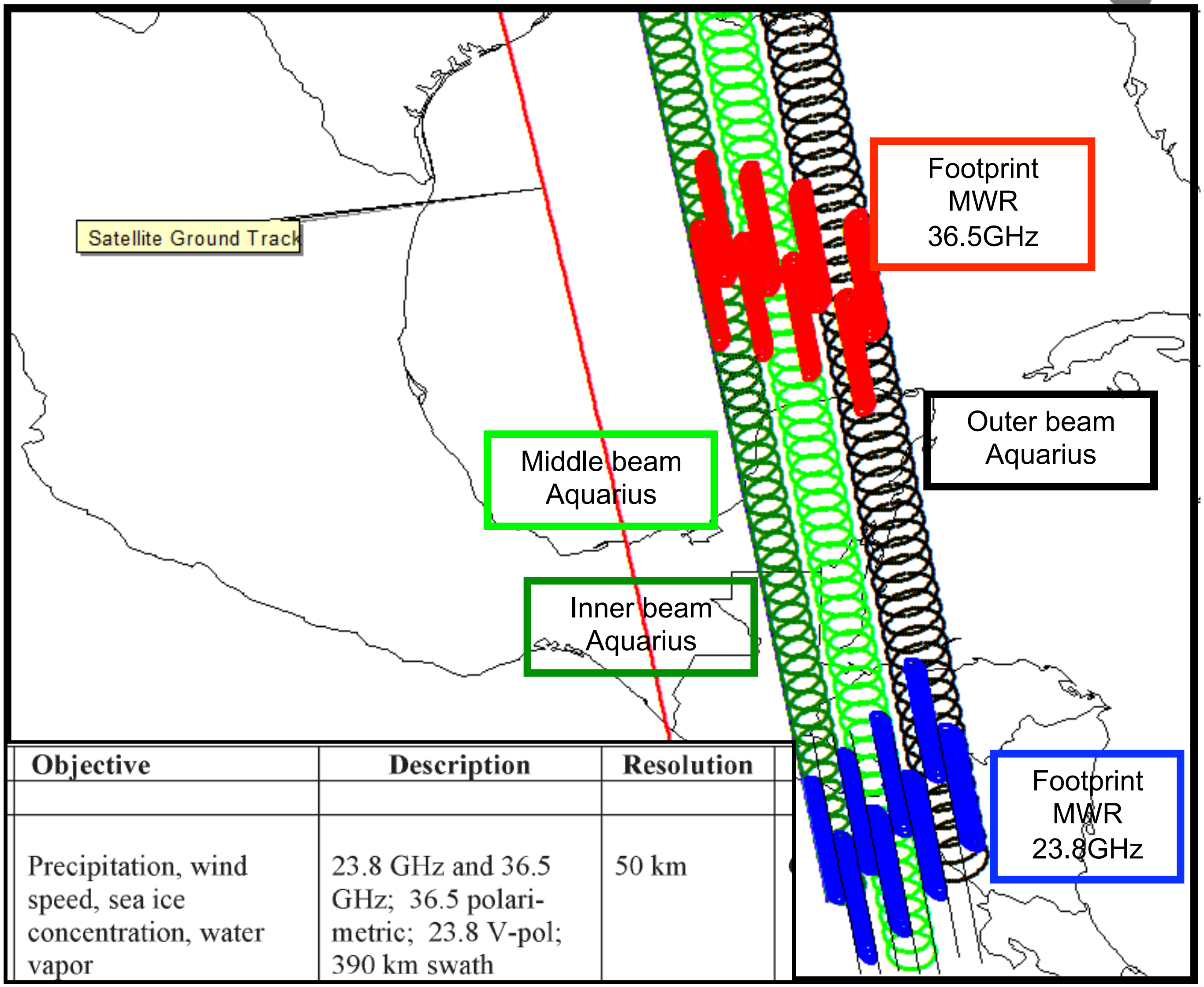
A new era begins !

AQUARIUS/SAC-D

CONAE Microwave Radiometer







Objective	Description	Resolution
Precipitation, wind speed, sea ice concentration, water vapor	23.8 GHz and 36.5 GHz; 36.5 polarimetric; 23.8 V-pol; 390 km swath	50 km

Arctic Ocean Coverage